Marine Environmental Data Service

Monthly Sea Surface Temperature for the Gulf of St. Lawrence

J.D.M. Weiler and J.R. Keeley

TECHNICAL REPORT NO. 7

November 1980

Government of Canada
Fisheries and Oceans

Gouvernement du Canada
Pêches et Océans

MARINE ENVIRONMENTAL DATA SERVICE

TECHNICAL REPORT NO. 7

Monthly Sea Surface Temperature for the Gulf of St. Lawrence

J.D.M. Weiler and J.R. Keeley

DEPARTMENT OF FISHERIES AND OCEANS
OTTAWA, CANADA

© Minister of Supply and Services Canada

Requests for copies should be sent to:

Marine Environmental Data Services Branch, Oceans and Aquatic Sciences, Department of Fisheries and Oceans, Ottawa, Ontario.

MEDS8000501KE

Ottawa
1980

ABSTRACT

This report presents the results of the analysis of about 35 years of sea surface temperature data measured by bathythermographs in the Gulf of St. Lawrence. The results are displayed as maps of monthly sea surface temperatures, and represent the average conditions to be found from the data. Optimum interpolation was used to analyze and contour the data. Use of this technique showed that yearly variations in the sea surface temperature are larger than measurement variations within a month. This fact allowed a considerable reduction in the necessary computations.

RÉSUMÉ

Le rapport présente les résultats de l'analyse de données sur les températures de surface de la mer pour environ 35 années, données mesurées au moyen de bathythermographes dans le golfe du Saint-Laurent. Les résultats sont exposés sous forme de cartes des températures de surface mensuelles de la mer et représentent les conditions moyennes que semblent révéler les données. Une technique d'interpolation optimale a permis d'analyser et de cerner les données. L'utilisation de cette technique a montré que les variations annuelles des températures de la surface de l'eau sont plus grandes que les variations des mesures au cours d'un mois. Ce fait a permis de réduire considérablement les calculs nécessaires.

ACKNOWLEDGMENTS

The authors would like to thank Mr. J. Taylor for his helpful assistance in the application of his (optimum interpolation) computer program to this problem.

CONTENTS

Page

Abstract ... iii

Résumé ... iii

Acknowledgements ... iv

Introduction ... 1

Mathematical Background ... 2

Data Analysis ... 3

Generation of Maps ... 13

Discussion of Results ... 17

References ... 17

Appendix: SST Maps ... 19

FIGURES

Figure 1 Area from which data set was extracted ... 4

Figure 2 Final clumping areas ... 7

Figure 3 SST vs Year for distinct clumping areas in distinct months ... 9

Figure 4 Whole Gulf ratio results ... 10

Figure 5 Two-degree square ratio results ... 11

Figure 6 Three distinct clumping areas ratio results ... 12

Figure 7 Smoothing of V ... 14

Figure 8 Smoothing of E ... 15

Figure 9 Smoothing of P ... 16

INTRODUCTION

An atlas presentation of the typical oceanographic conditions to be found in an area is useful in a variety of ways. For those planning an experiment, the foreknowledge of what is likely to be found assists in the design of the field program. For those doing environmental assessments, it establishes a baseline to which changes may be compared. For those analysing data, it is of use to determine if the newly acquired data are markedly different from historical records. Where there is a large difference, it may indicate erroneous measurements.

There are many problems in the production of an oceanographic atlas most of which stem from the paucity of data either over an adequate area or over a long enough period of time. It is advantageous to deal with a large area since it includes more data and may allow interpolations to fill in areas where data are missing. More often, the severest constraint is that observations do not go back far enough in time to resolve long period fluctuations. It is important in the generation of an atlas to consider the effects of the sampling and to compensate for the resulting problems as much as possible.

There are some instances where the amount of data makes it possible to produce useful charts of oceanographic parameters. One such area is the Gulf of St. Lawrence. The results presented here are the sea surface temperatures (SST) in each month as measured by a bathythermograph (BT). The analyses were restricted to SST in order to develop the necessary data handling procedures. Now, it would be possible to handle in a similar way any parameter measured at any depth. The data were restricted to observations from BT's for two reasons. Firstly, of all observations taken in the Gulf, those made using BT's are the largest fraction. Secondly, if observations from different instruments were used it would have been necessary to ensure the interchangeability of the data.

The charts of SST were produced using the techniques of optimum interpolation. In their production, it was found that a simplification of the original analysis scheme was possible because of the large year to year fluctuations. This will be dealt with in detail and is reflected in the smooth SST contours which were generated.

MATHEMATICAL BACKGROUND

Related to the classical methods of Gaussian regression and correlation, optimum interpolation (OI) is a process to determine unknown values of a function from known values. That is, given values of a function, $f(x)$, at points $p_1, p_2, \ldots, p_n$ where $p_1, p_2, \ldots, p_n$ form a finite subset **P** taken from a realm **V**, we want to determine $f(x)$ for any x within **V**. OI methods involve minimizing the mean-square interpolation error, where

$$f(x) = \hat{f}(x) + \epsilon(x)$$

such that $\hat{f}(x)$ is the interpolated value for $f(x)$ at a point x within **V**, and $\epsilon(x)$ is the associated error of interpolation.

Closely connected with OI is the concept of structure functions. Structure functions are formulas which mathematically model data sets. They are related to correlation functions in that both deal with regression among variables, and functions of variables. In particular, structure functions attempt to relate functions, such as sea surface temperature (SST), to the distance between the different locations at which values for the function are known (i.e. $f(x)$ depends upon $\|x - x_o\|$).

In our basic assumptions about the structure function, G, we assume that it is both homogeneous and isotropic. This facilitates computation and assures us of solutions. We also assume the interpolation errors, $\epsilon(x)$, are uncorrelated with both $f(x)$ as well as with each other. That is -

$$\text{cov}\ (\epsilon(x),\ f(x)) = 0$$

$$\text{and,}\ \text{cov}\ (\epsilon(x),\ \epsilon(y)) = \begin{cases} 0, & x \neq y \\ 1, & x = y \end{cases}$$

Under these assumptions it has been shown (GANDIN, 1963) that the structure function, G, is indeed a function of the distance separating data observations alone. That is -

$$G(x) \rightarrow G(r) \mid r = \|x - x_o\|, \text{ where x and } x_o \text{ are within } \mathbf{V}$$

He has also shown that G relates to the "estimated" structure function, $\hat{G}$, in the following way

$$G(r) = \hat{G}(r) - 2E + G(0), \text{ where E is the root mean square (rms) random observation error.}$$

For facility of computation we have used a "weighted-mean" version to arrive at an estimate of the mean of the true SST, $\hat{\theta}$, for a fixed month and location, over all years. A weighted-mean method refers to a systematic weighting and averaging of observed values. That is -

$$\hat{\theta} = \sum_i w_i\ \phi_i$$

where w_i is a normalized weighting factor,

and, ϕ_i is the observed data, in this case, SST.

Under our previous assumptions it has been shown (BRETHERTON, DAVIS, and FANDRY, 1975) that weighting factors, w_i, can be generated by setting, for each month and location,

$$w_i = ((\sigma^2 + E/N_i) \sum_j (\sigma^2 + E/N_j))^{-1} \text{ and} \qquad (1)$$

$$\phi_i = \sum_{j=1}^{N_i} T_{i,j}/N_i,$$

where, σ^2 is the variance of the signal,

$T_{i,j}$ is the jth observation in the ith year

N_i is the number of observations in the ith year.

For computational purposes, the computer program (hereafter referred to as CMO) for the contouring of oceanographic data (TAYLOR, 1976) uses the structure function:

$$C(r) = -\tfrac{1}{2}\hat{G}(r)$$

The first value, C(O), will be the negative of the rms random error, -E. $\hat{G}(r)$, the estimated structure function, is generated from the data by partitioning the two -tuples of data into twenty (20) sets corresponding to the distance, r, which separates them. A fit is then made of the experimental $\hat{G}(r)$ to the form

$$C(r) = -\tfrac{1}{2}\hat{G}(r) = (V-E)\exp[-\tfrac{1}{2}(r/s)^P] - V \qquad (2)$$

chosen because it yields a good fit in most cases and, in addition, at r = O, C(r) = -E, as it should. The parameters V,E,S, and P are selected by a least-squares error test.

DATA ANALYSIS

The data set was extracted from the Bathythermograph Data Base of the Marine Environmental Data Service (MEDS). It consisted of over 21,000 stations taken from the area illustrated in Figure 1. The stations spanned the years from 1944 to 1979, and included all months.

All computer programs were written in FORTRAN, and were run on a CDC CYBER 74 computer in Ottawa.

In order to understand the physical significance of the weighting formula, (1), we have included the following brief interpretation. Firstly, the term σ^2, representing the variance of the signal, incorporates into w_i the necessary allowance needed by having estimates, $\hat{\theta}_i$, which are not all the same. Should all of the estimates be the same (i.e. $\hat{\theta}_1 = \hat{\theta}_2 = \ldots = \hat{\theta}_2$) than σ^2 equals zero (0), and the formula for the calculation of $\hat{\theta}_i$ becomes

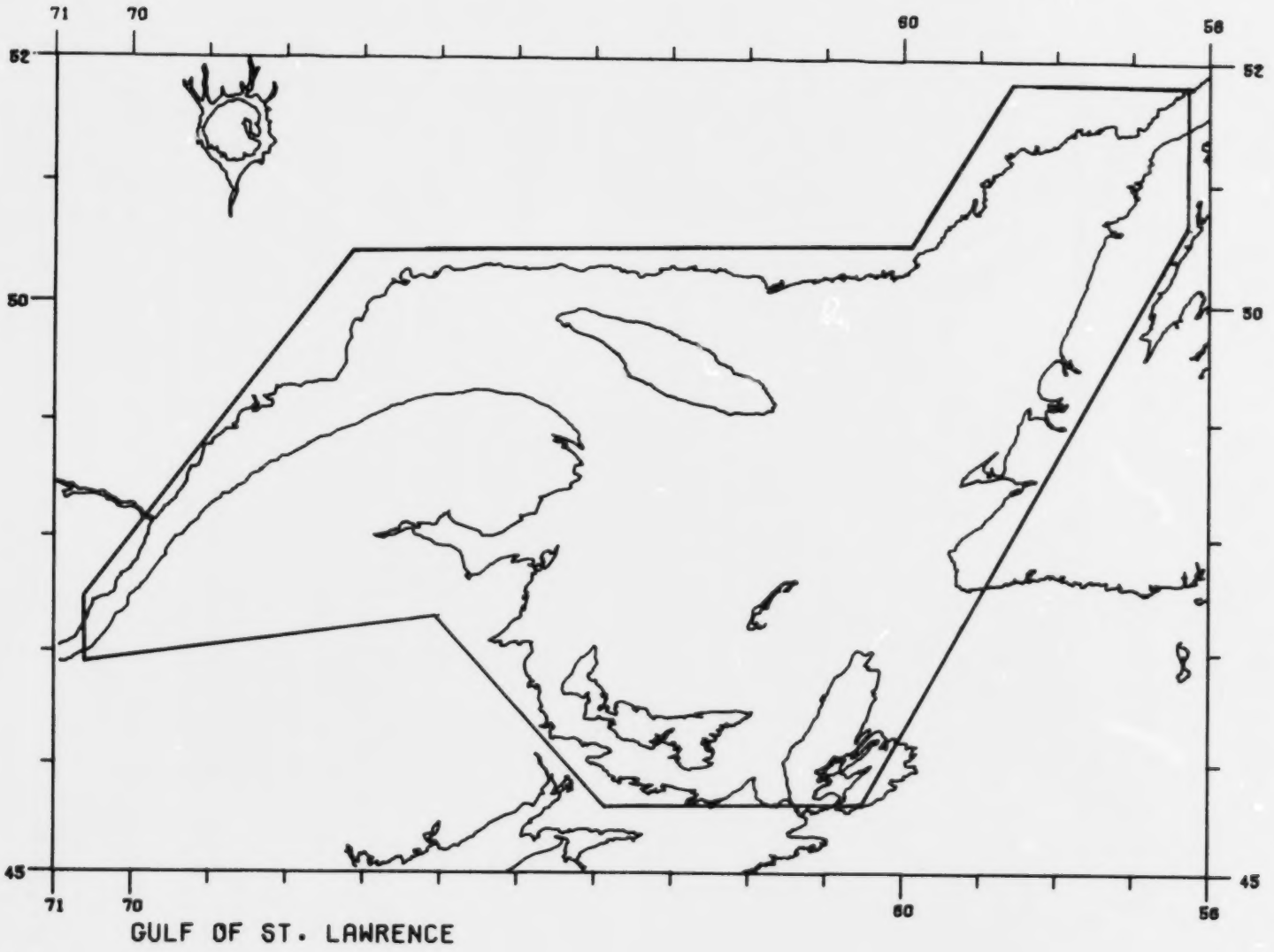


Figure 1 Area from which data set was extracted

$$\hat{\theta}_i = \sum_j N_j Q_j / \sum_k N_k$$

which is a simple weighted mean formula which weights each year's ϕ_i with respect to the number of observations, N_i, in that year. Secondly, the term, E, representing the variance of the noise, incorporates into w_i the necessary allowance needed by having observations, ϕ_i, which are not all the same. If there is no noise then E equals zero (0), and our formula for the calculation of $\hat{\theta}_i$ becomes

$$\hat{\theta}_i = \sum_{j=1}^{L} \phi_j / L$$

which is the arithmatic mean, as it should be. Finally, if the number of observations in each year is the same (i.e. $N_1 = N_2 = \ldots N_L = N$), then all the weights, w_i, are equal, as they should be.

As is evident, through a quick scrutiny of equation (1), if it happens that the ratio:

$$\sigma^2 : (E/N_i) \qquad (3)$$

is either consistently greater than ten to one (10:1) or consistently less than one to ten (1:10) then a significant simplification of equation (1) with less than ten percent (10%) loss of information, is easily available. In the first case, the implication is that if the variance of the noise divided by the number of observations (i.e.E/N_i) is of little significance to equation (1), the elimination of the term (E/N_i) is justified. This would simplify our weighting formula to

$$w_i = 1/L$$

In the second case, the implication is that if the variance of the signal (i.e. σ^2) is of little importance to equation (1), then the elimination of the term (σ^2) from equation (1) is justified. This would yield a simplified weighting formula of

$$w_i = N_i / \sum_j N_j$$

In either case a significant reduction in the amount of computation would result. We will explore these two possibilities in detail further on.

For subsequent uses it was first necessary that we determine a rough approximation of the correlation distance, with respect to SST, for the Gulf of St. Lawrence. We did this by allowing CMO to determine an approximate value for each month using the entire SST data observations set. The twelve resulting values were then averaged to give about 600 km, and this value was used as our rough SST correlation distance approximation.

Because the correlation distance was much larger than the sample spacing we could simplify our data set. We began by incorporating all of our observations into a smaller number of data 'clumps'. It was necessary, in order to preserve accuracy, as well as to generate informative maps, that enough data observations be included in each data clump. We wanted to keep the number of data clumps small enough so as to facilitate computations, yet, at the same time, large enough so that over-simplified maps would not result. It was also

necessary, to ensure against an over-smoothing of our data; that the mean cross-sectional distance of our "clumping areas" be much less than the mean correlation distance for the entire Gulf.

We first partitioned the Gulf into fifty-six (56) one-degree coted squares. This ensured that the mean cross-sectional distance of each clumping area was less than the mean correlation distance for the entire Gulf. We then examined each of these one-degree coted squares to see if they were interrupted by a significant land mass (i.e. Prince Edward Island, Anticosti Island, etc.). If it happened that a coted square was so interrupted, we further partitioned that square into two smaller clumping areas. This minimized the extent to which the land masses would bias our data clumps (i.e. by positioning them over land, or incorporating SSTs from opposite sides of a land mass into the same data clump). We finally checked each clumping area to ensure that it contained enough data observations to make a meaningful contribution to our analyses (i.e. an approximate average of 5 observations per month in clumping areas on the perimeter of the Gulf, increasing to an approximate average of 40 observations per month in clumping areas at the center of the Gulf). It is possible that a smaller number of clumping areas would have been sufficient, however, the clumping areas were certainly adequate for our purposes. The final clumping areas are illustrated in Figure 2.

In each of the sixty-four (64) resultant clumping areas we created for each month, a data clump which reflected the observed SST as well as the positions of those observations. We did this by assigning each clump to the average location of the data observations within each clumping area. That is -

$$(X_{i,j,o,o},\ Y_{i,j,o,o}) = \sum_{k=1}^{L_{i,j}} \left(\sum_{l=1}^{N_{i,j,k}} (X_{i,j,k,l},\ Y_{i,j,k,l})/N_{i,j,k} \right)$$

where $X_{i,j,k,l}$ and $Y_{i,j,k,l}$ are, respectively, the latitude and longitude of the lth observation in the ith clumping area for the jth month of the kth year. Note if $k = l = o$ then the point is a data clump.

$N_{i,j,k}$ is the number of observations in the ith clumping area for the jth month of the kth year.

$L_{i,j}$ is the number of years in which observations were made in the ith clumping area and the jth month.

A mean value, $\phi_{i,j}$, was then assigned to each clumping location according to the following formula

$$\phi_{i,j} = \sum_{k=1}^{L_{i,j}} \beta_{i,j,k}/L_{i,j}$$

$$\text{where } \beta i,j,k = \sum_{l=1}^{N i,j,k} T_{i,j,k,l}/N_{i,j,k}$$

and $T_{i,j,k,l}$ is the lth temperature observation in the ith clumping area for the jth month of the kth year.

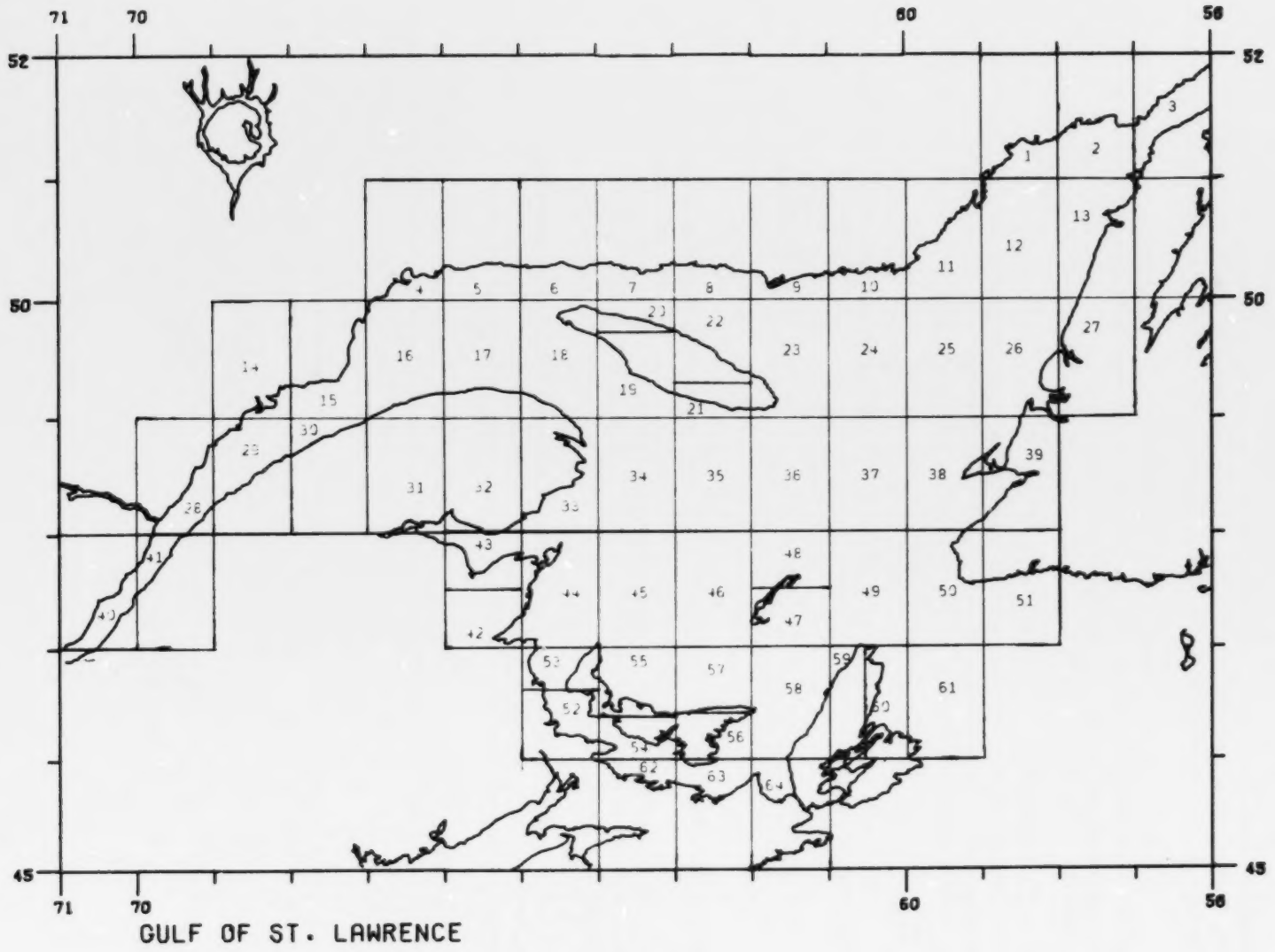


Figure 2 Final clumping areas

Our assumption, in creating the structure function, that year to year SST observations were uncorrelated in individual clumping areas was checked by surveying plots of SST vs YEAR for a number of distinct clumping areas and months. The results of five (5) such plots are illustrated in Figure 3. The five (5) shown were selected because they had a relatively large number of years in which observations were made.

As previously described we then performed our "ratio" calculations (equation 3) hoping to be able to simplify the weighting formula. Since the mean correlation distance for the Gulf was greater than one-half (½) of the mean cross-sectional distance of the entire Gulf, we first performed our ratio calculations using the entire SST data set. This was the alternative to using a number of data sets restricted to smaller segments of the Gulf.

The results of the calculations on the entire data set (Figure 4) yielded a minimum ratio ($\sigma^2/(E/N_i)$) of approximately 35:1 in the month of January. In each of the remaining months the ratio was greater than 50:1. This demonstrated the relative unimportance (less than 2% in all months save January) of the term E/N_i in the calculation of our weighting factors, w_i, in equation (1).

We, therefore, eliminated the term (E/N_i) from the weighting formula (equation 1) to arrive at our final, and much simpler, weighting formula

$$\hat{\theta} = \sum_{i}^{L} \phi_{i/L}$$

easily recognized as the arithmatic mean of the average of observed temperatures over L years.

What this means, in real terms, is that under suitable circumstances the number of observations in different years does not significantly affect the required OI calculations involving the estimation of the mean of the true SST.

We checked our ratio results over the entire Gulf by using data restricted to smaller areas of the Gulf. These areas included a two-degree square in addition to three of our clumping areas. The smaller areas chosen were selected because they had a relatively large number of data observations.

The two degree square calculations produced results (Figure 5) which, except for the months of March and April, upheld our original findings. The results of March and April's calculations are readily explained by the fact that they were based on 2 and 3 years of data respectively, and hence are not particularly reliable. The average number of years on which the other months' observations were calculated was over 19.

The three clumping areas in which the ratio calculations were performed produced similar results (Figure 6); justifying the elimination of the term (E/N_i) from the weighting formula (equation 3).

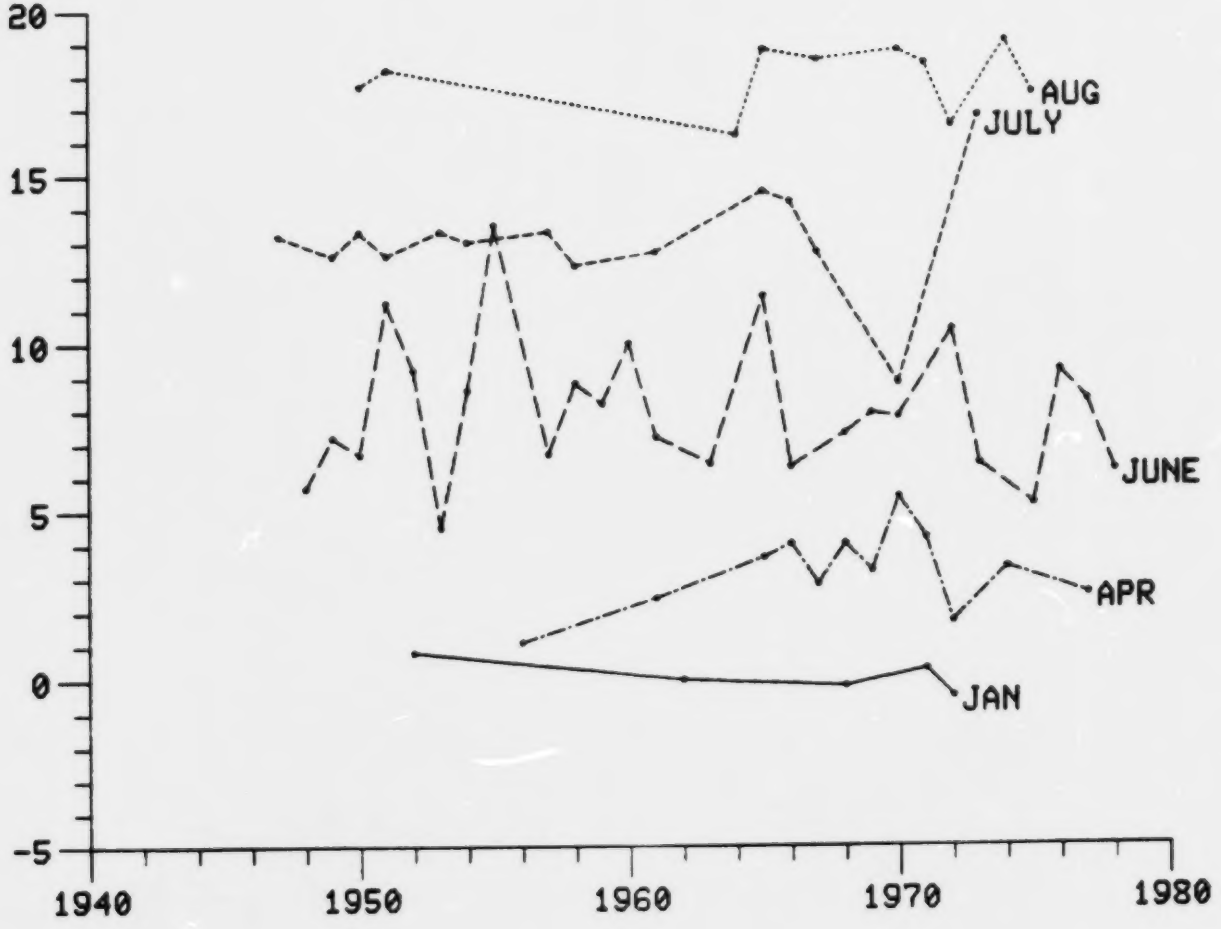


Figure 3 SST vs Year for distinct clumping areas in distinct months

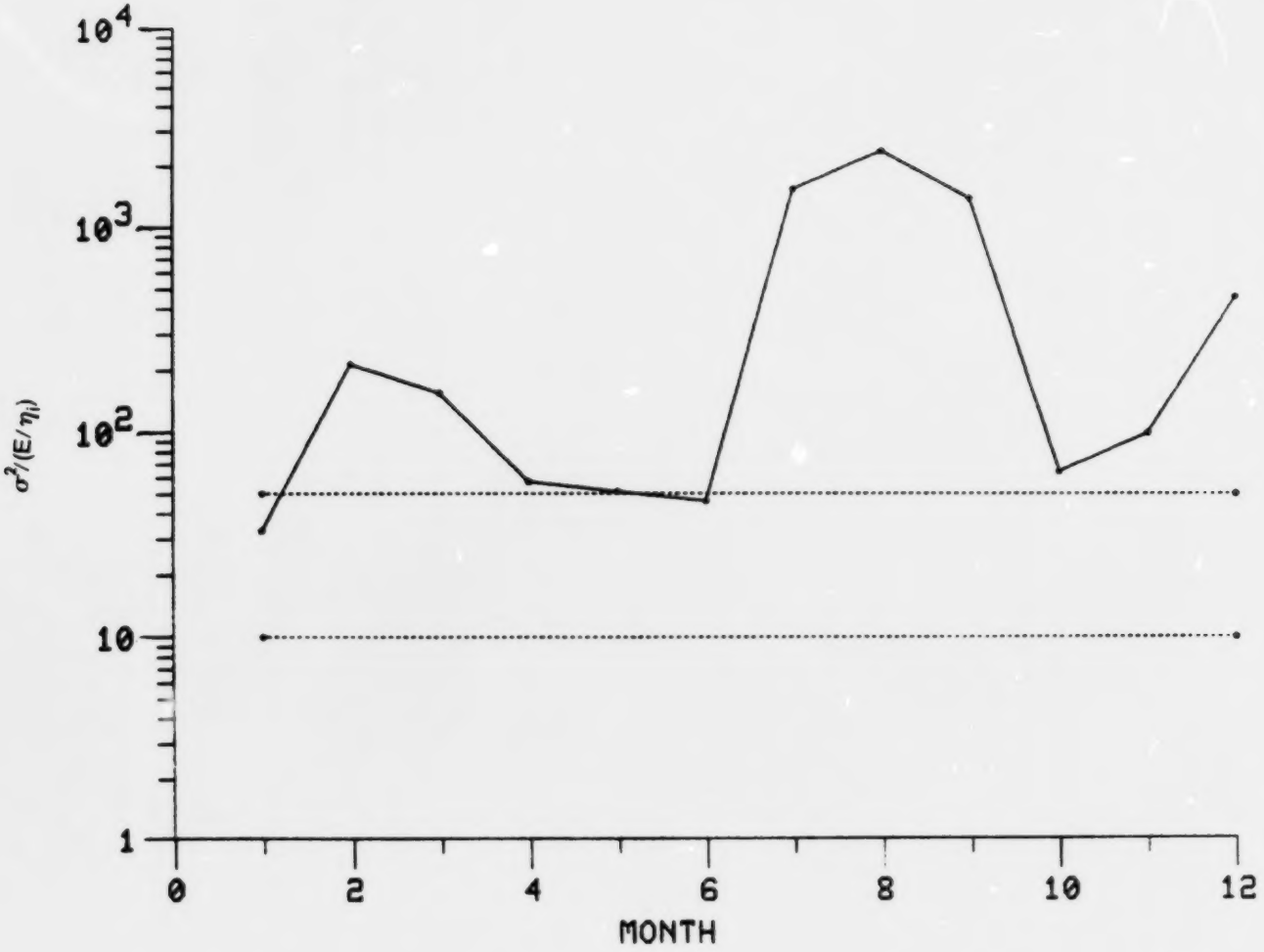


Figure 4. Whole gulf ratio results. Dotted lines represent relative sizes of E/η_i to σ^2 of 2% and 10%.

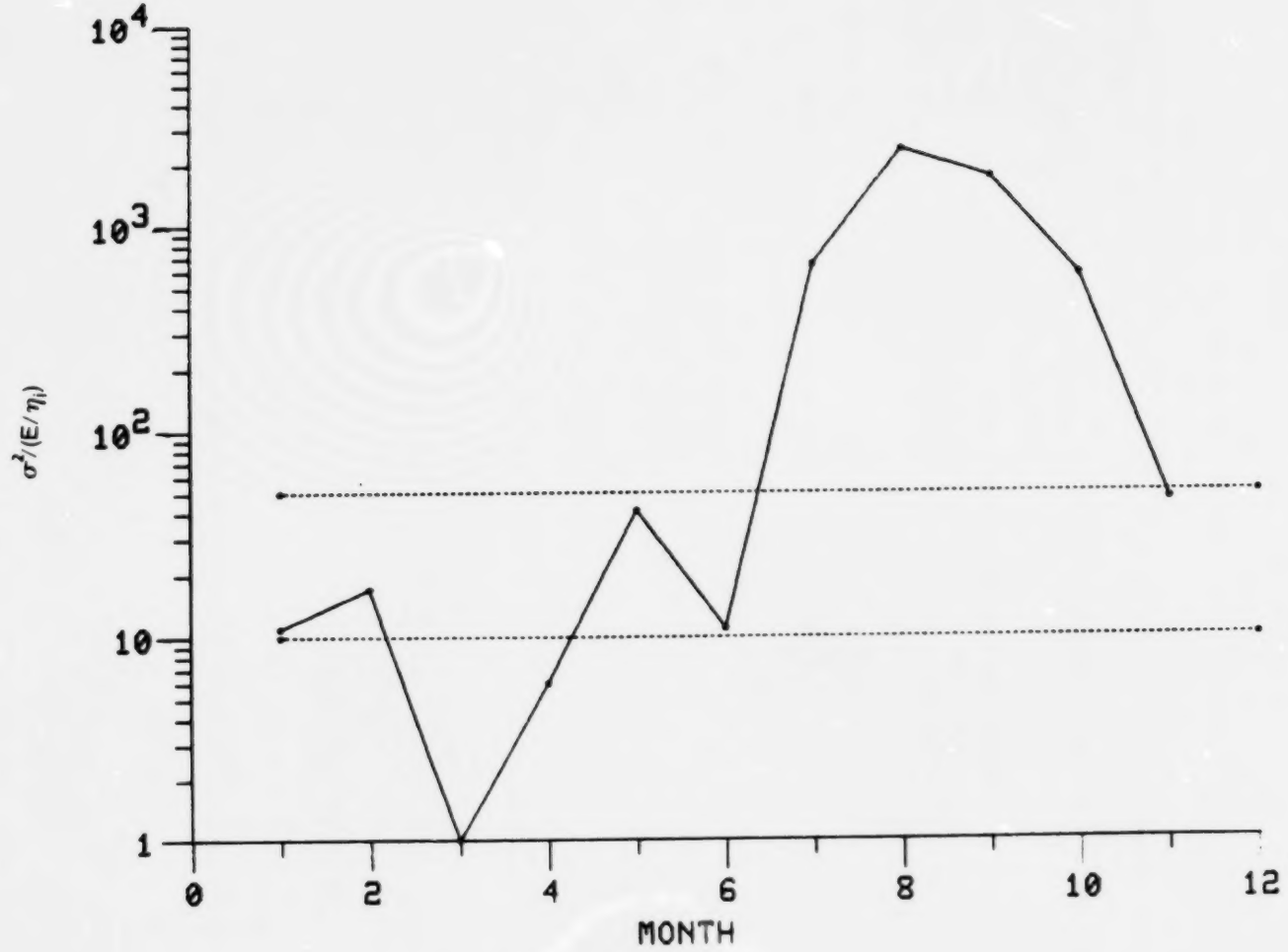


Figure 5. Two-degree square ratio results. Dotted lines represent relative sizes of E/η_i to σ^2 of 2% and 10%.

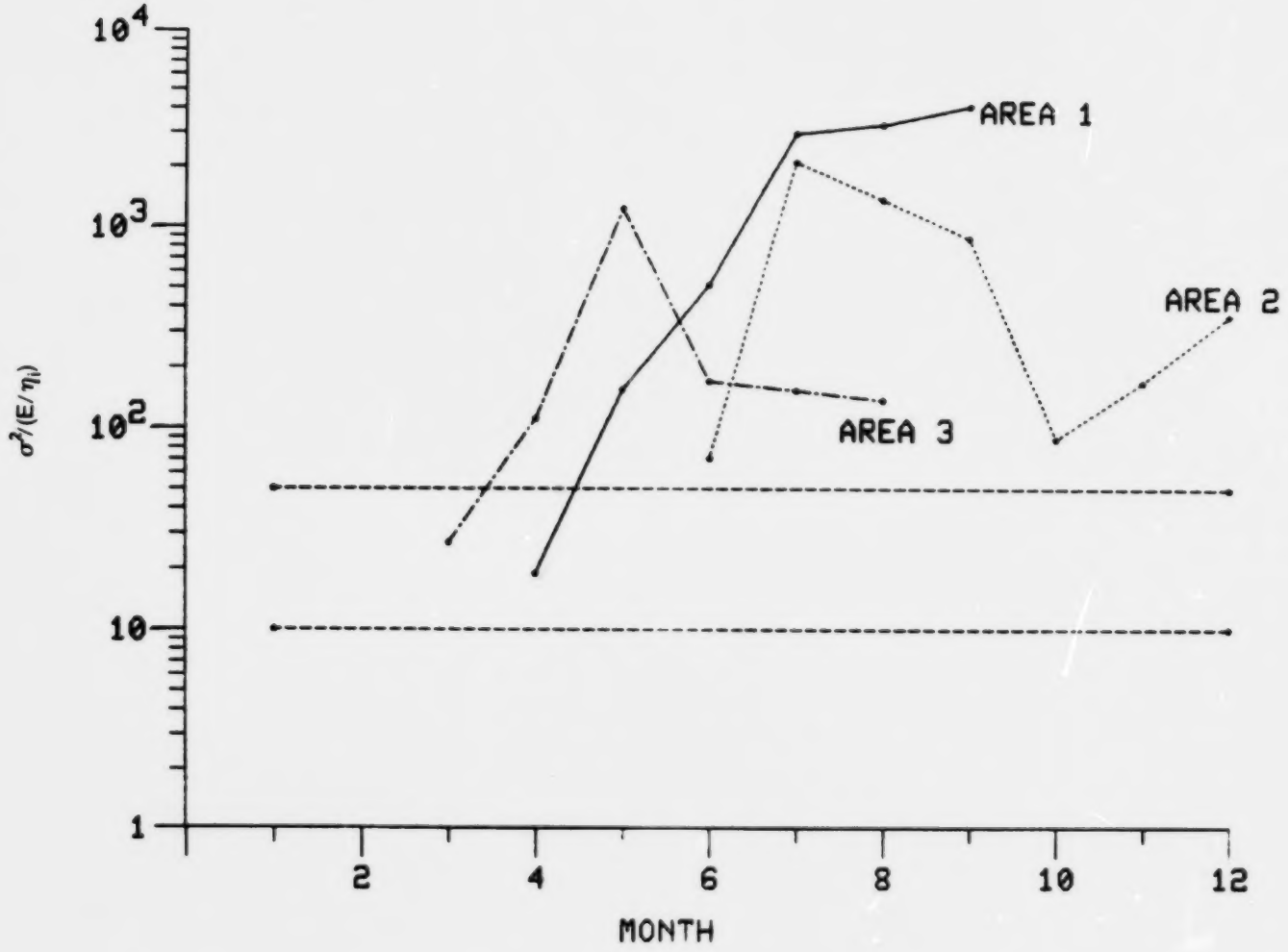


Figure 6. Three distinct clumping areas ratio results. Straight dashed lines represent the relative sizes of E/η_i to σ^2 of 2% and 10%.

GENERATION OF MAPS

The maps were produced using the CMO program. We smoothed the contours, so as to minimize the effect of aberrant data clumps, by refining the values used in the program's structure function (equation 2). Corresponding to the number of parameters in the structure function we used a four (4) stage refinement process. We first ran CMO allowing it to determine values for V,E,S, and P (equation 2). We then fitted a smooth curve (Figure 7) to the roots of the values obtained for V from the first running of CMO. Using these fitted values for V we reran CMO allowing it to determine new values for each of the parameters E,S, and P. We subsequently fitted a smooth curve (Figure 8) to the roots of the values obtained for E from the second running of CMO. Using these fitted values for E, along with the fitted values for V, we reran CMO allowing it to determine new values for each of the parameters S and P. We then fitted a smooth curve (Figure 9) to the values obtained for P from the third running of CMO. This final run yielded the smoothed parameters from which we could generate SST contours.

We chose contour intervals for each month which produced an "uncluttered" appearance, yet continued to reflect a significant portion of the information. These contours were subsequently blanked out when the error in their interpolation fell outside a suitable range. This range was chosen to block out areas further than approximately two hundred (200) kilometers from the nearest data clump. They were also blanked out when the contour lay over land.

Error contour levels were then chosen and incorporated in the final maps. They were chosen on the same basis as were the SST contours.

The final maps are shown in the Appendix.

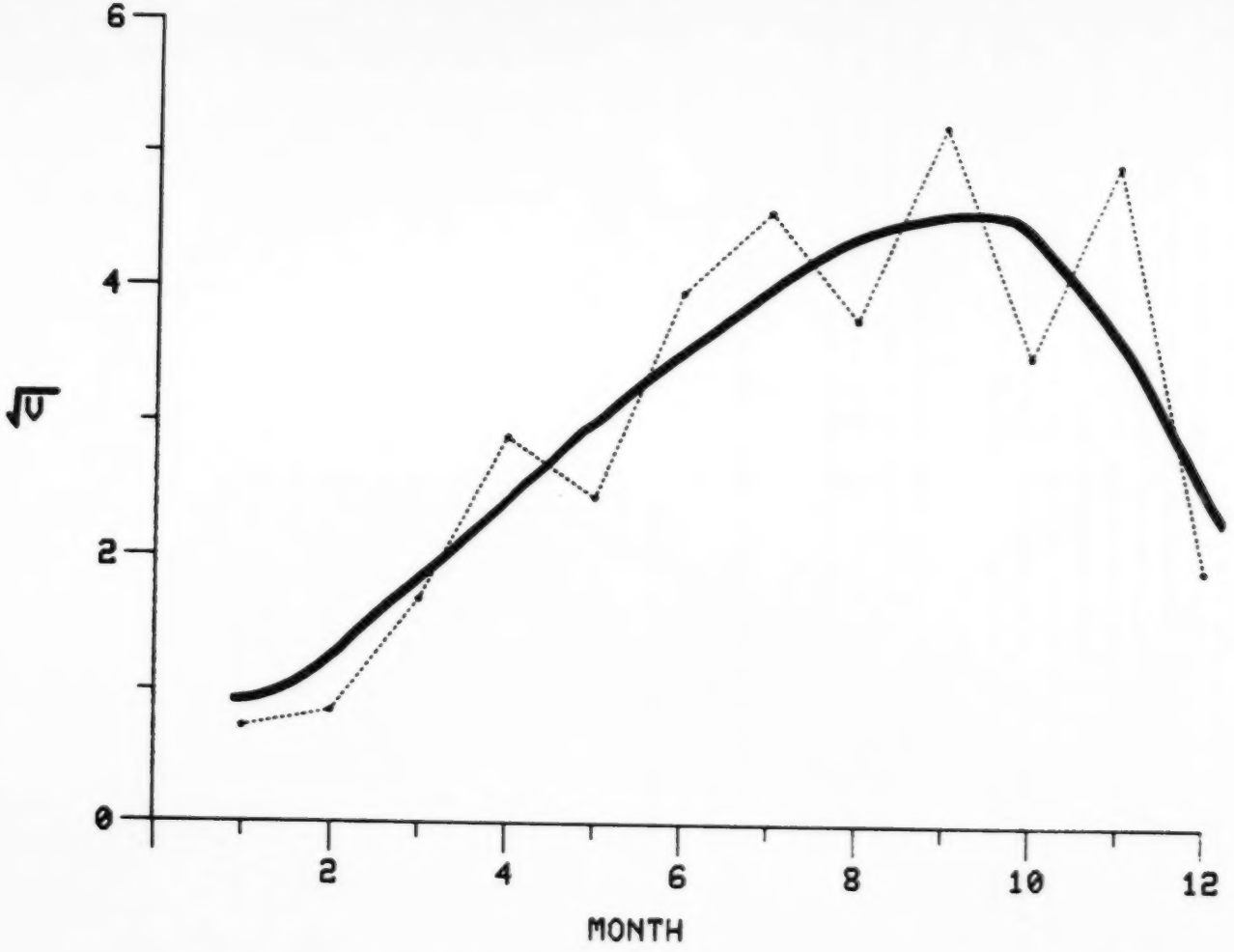


Figure 7. Smoothing of V. The dashed curves are the values determined by CMO, the solid line is the smoothed curve.

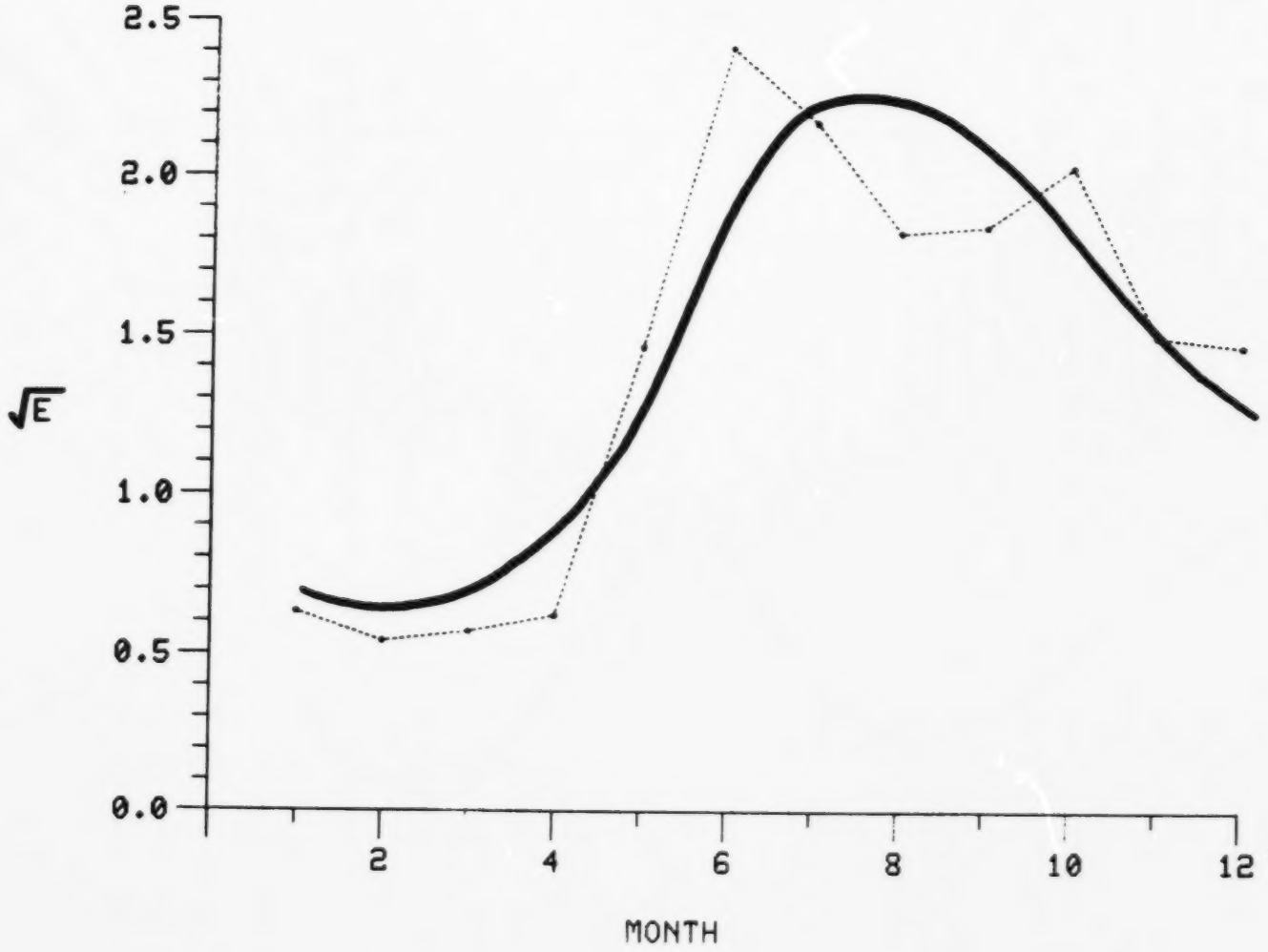


Figure 8. Smoothing of E. The dashed curves are the values determined by CMO. The solid line is the smoothed curve.

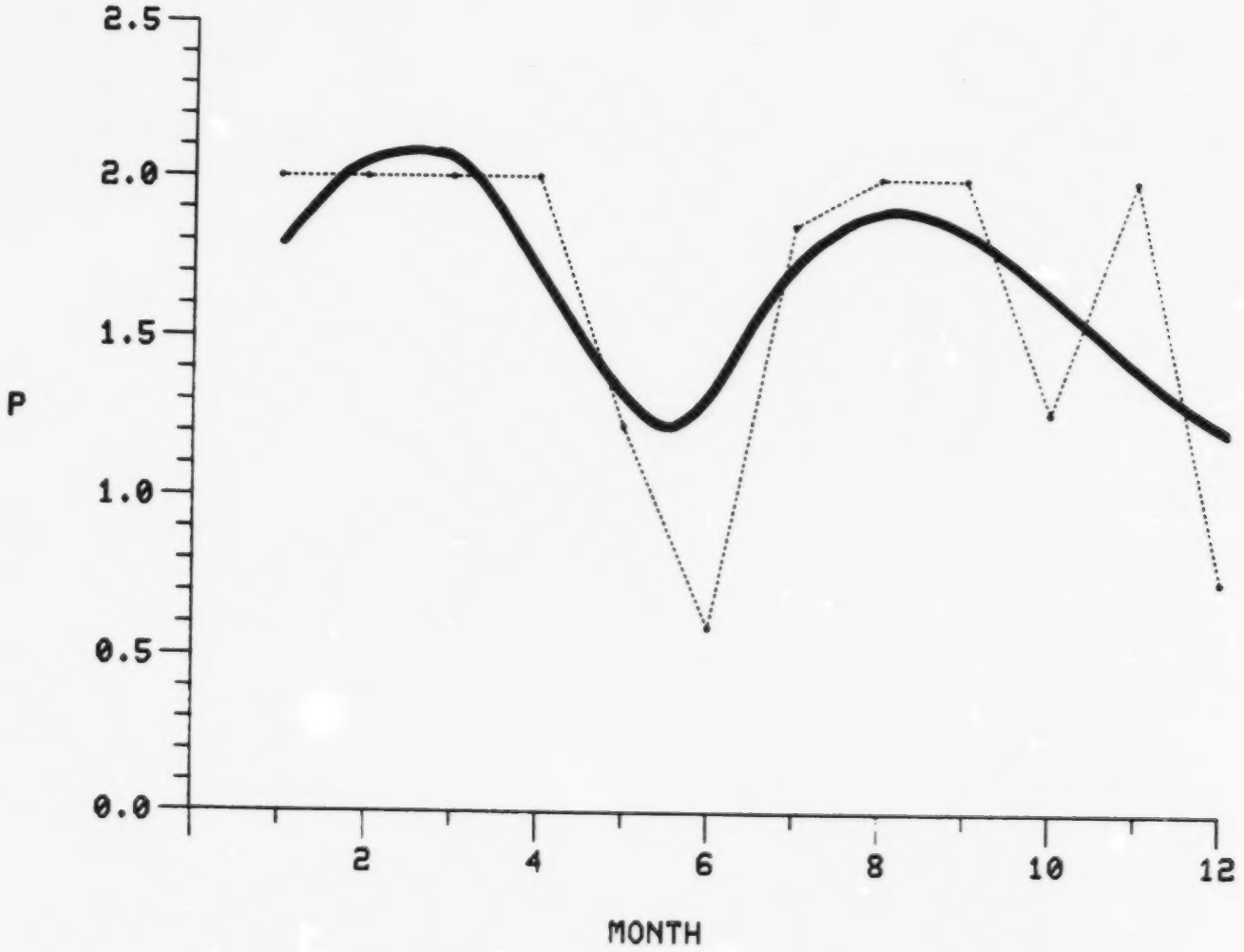


Figure 9. Smoothing of P. The dashed curves are the values determined by CMO, the solid line is the smoothed curve.

DISCUSSION OF RESULTS

In generating this type of map it is inevitable (because of bad, or lacking data, etc.) that some amount of error is present. We have tried to give an estimate of that error by displaying the error contours on the SST maps. The data analysis is also a source of error in as much as the data clumps, although they reflect the data observations in their respective clumping areas, still do not include all of the information.

In the process of fitting and refining of the parameters of the structure function different months will have either an overestimated or underestimated structure function. For the months in which the structure function is overestimated, the maps generated will appear smoother, with fewer peaks than they actually should (for example maps of March and April). For the months in which the structure function is underestimated the maps produced will appear less smooth, with more peaks than they actually should have (for example July and November).

Because of the methods employed, the maps do not give an accurate portrayal of the true SST in small areas of the Gulf (less than one degree squares). For this reason they must be viewed in total and used only for the purpose of obtaining general trends in moderately large areas of the Gulf (greater than two degree squares).

Some general trends were clearly evident from a survey of the maps generated. In eleven months the SST increased as one proceeds from North to South. The map for the month of February is noticeably different in as much as the upward trend of temperature contours follows a West to East pattern as opposed to the typical North to South one. Particularly in May, June, and July a cool area near the mouth of the Saguenay River is clearly seen.

REFERENCES

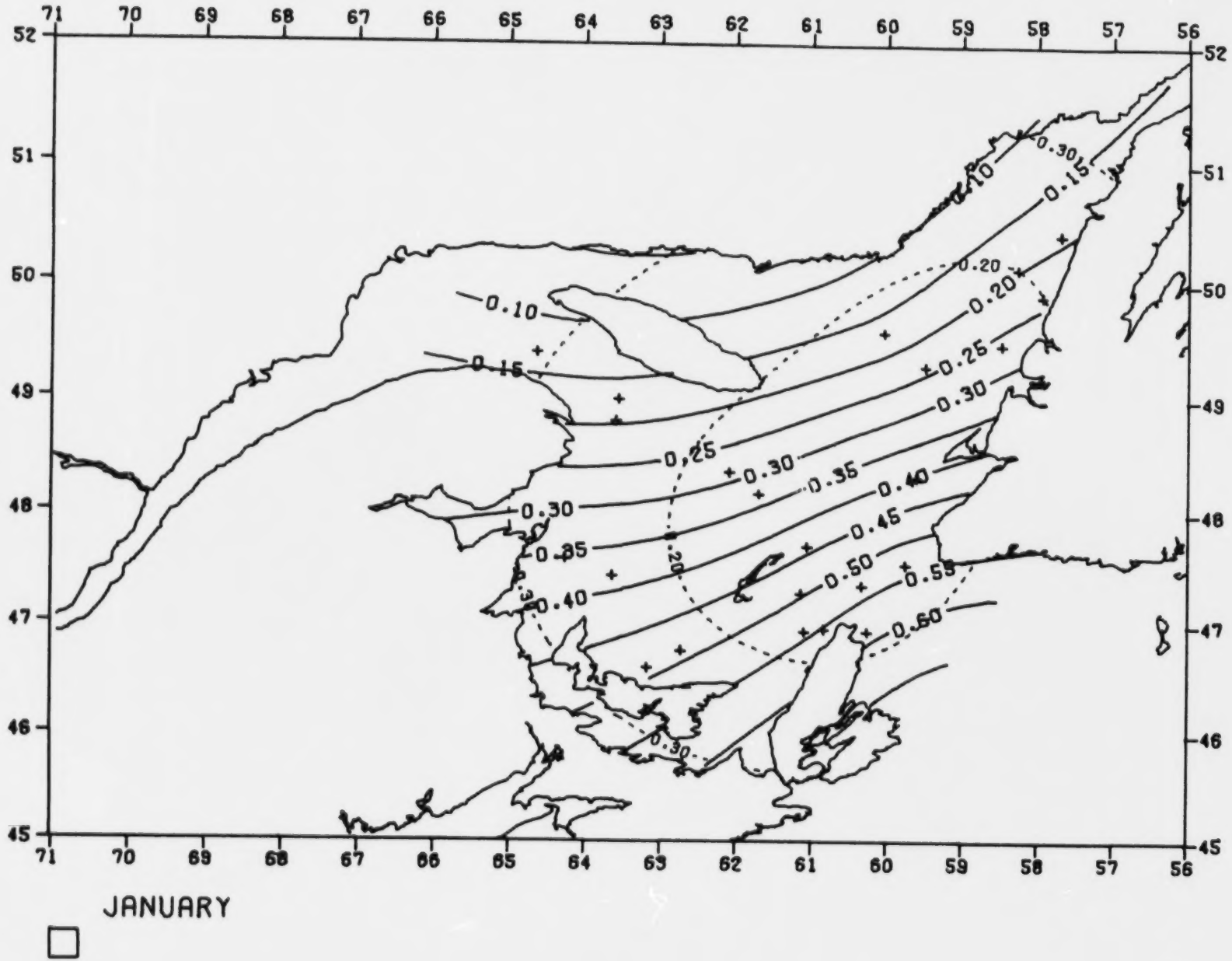
1. BRETHERTON, F. P., R. E. DAVIS, C. B. FANDRY. A technique for objective analysis of oceanographic experiments applied to MODE-73, Deep Sea Research, V. 23, p. 559-582, 1976.

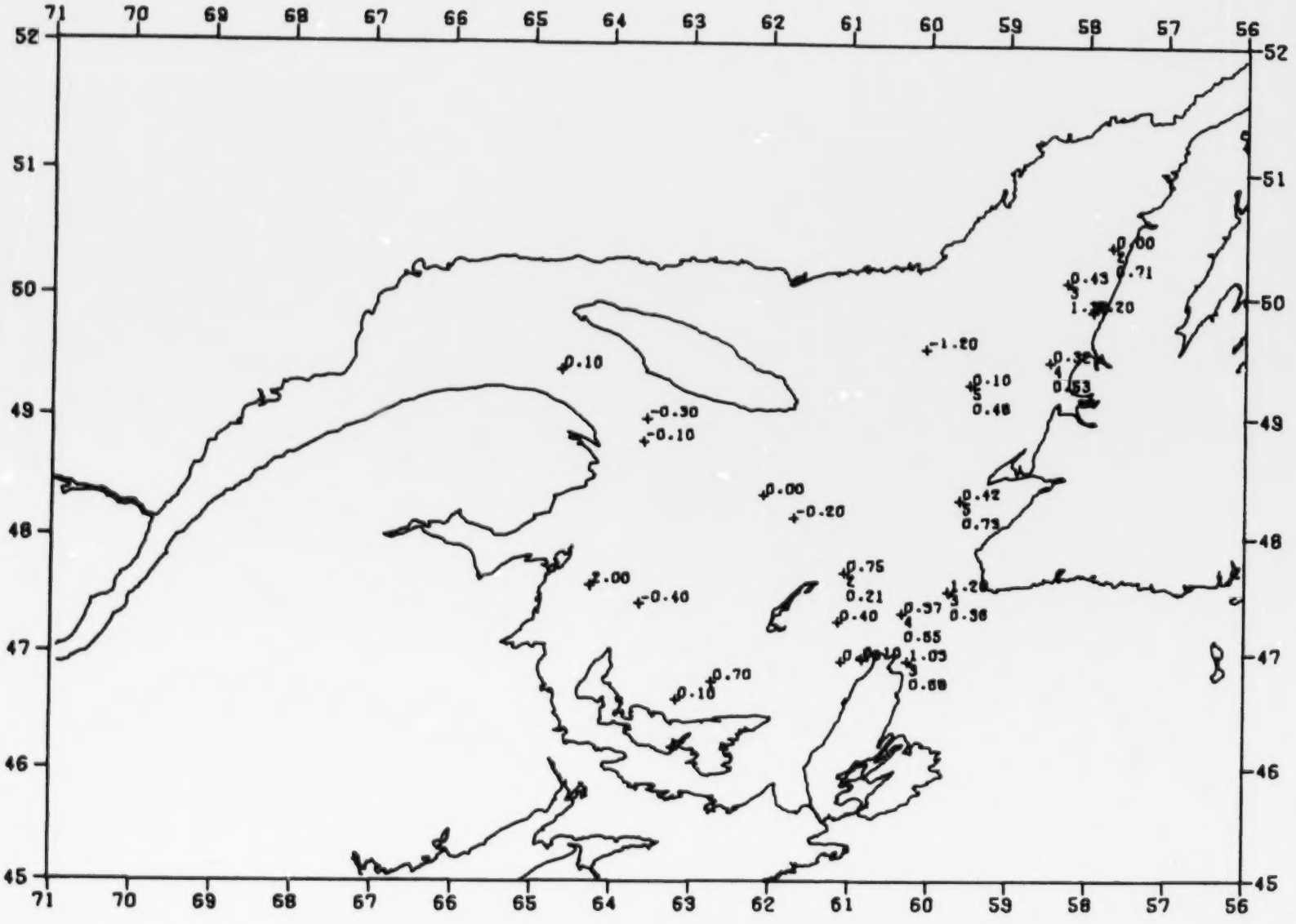
2. GANDIN, L. S. Objective analysis of meteorological fields, Israel Program for Scientific Translation, Jerusalem, 1965.

3. TAYLOR, J., CONMAP: A Computer Program for the Contouring of Oceanographic Data, Marine Environmental Data Service, T.N. #12, 1976.

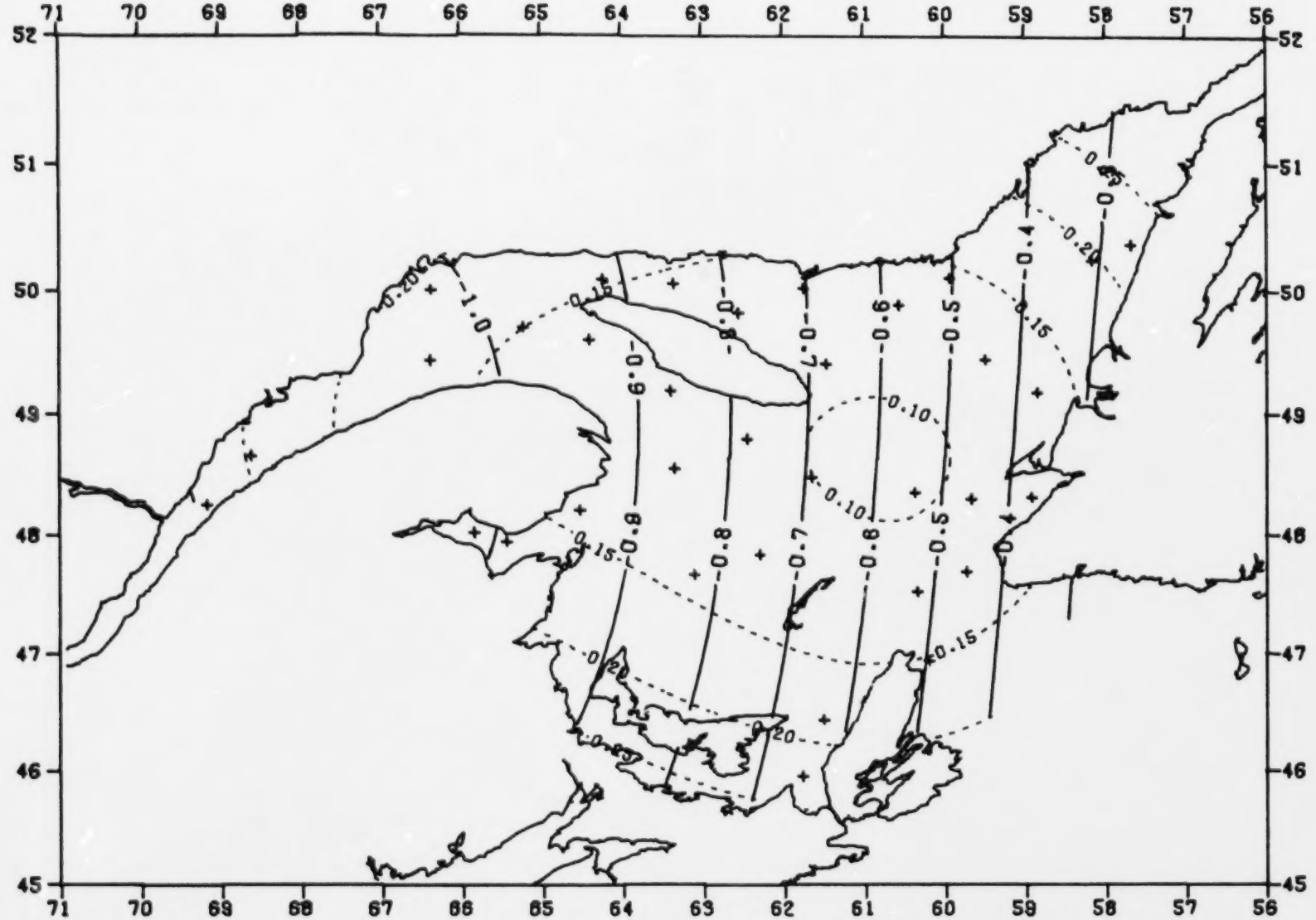
APPENDIX

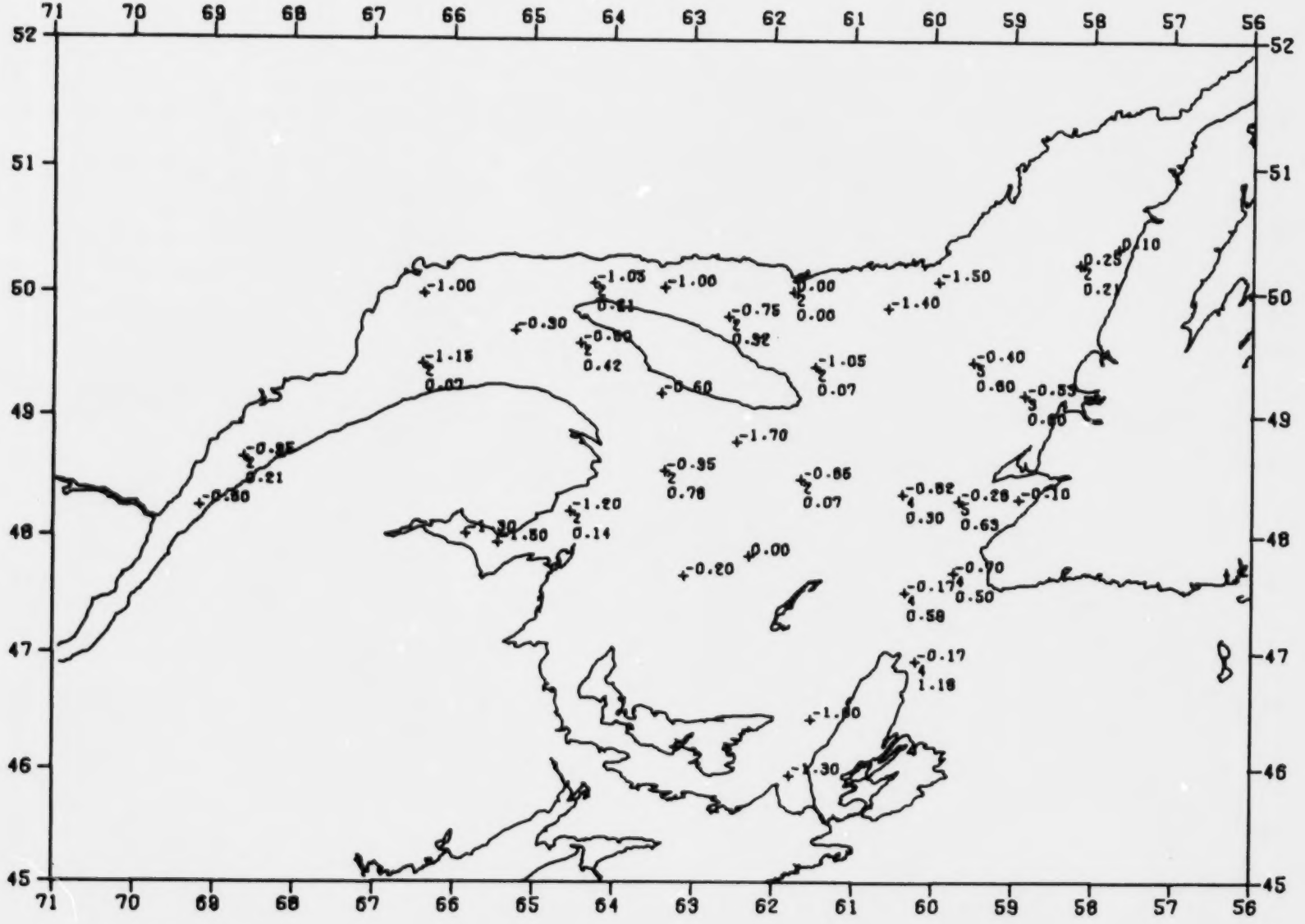
The SST maps are shown here. The first map for each month includes SST contours in degrees C (solid lines), interpolation error contours (dashed lines), as well as a mark (+) at each data clump location. The second map for each month marks the location of each data clump (+), along with the parameter value associated with it. If the data clump includes SST observations from more than one (1) year, then the number of years in which observations were made along with the standard deviation of the observations are also given.

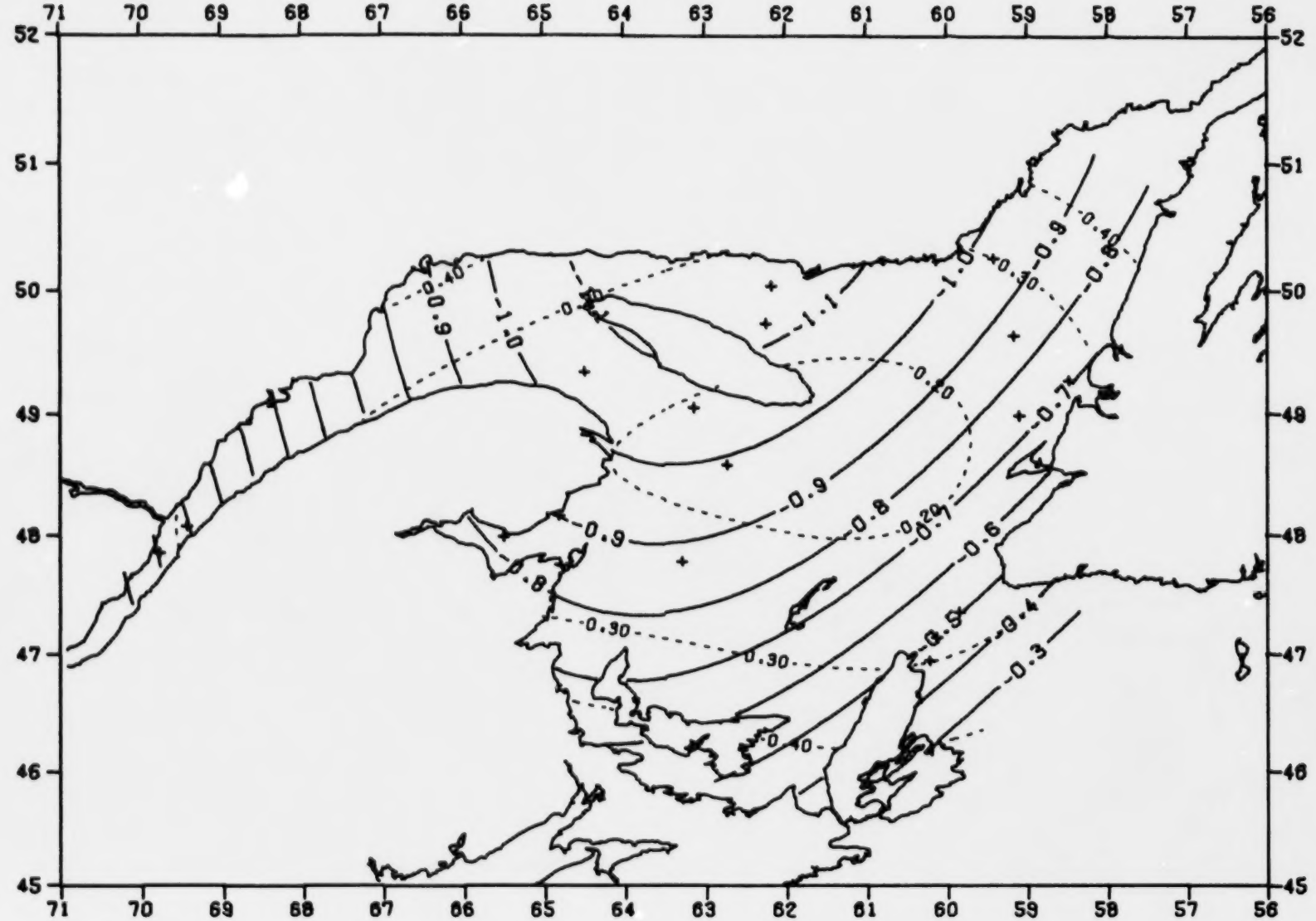

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
JANUARY

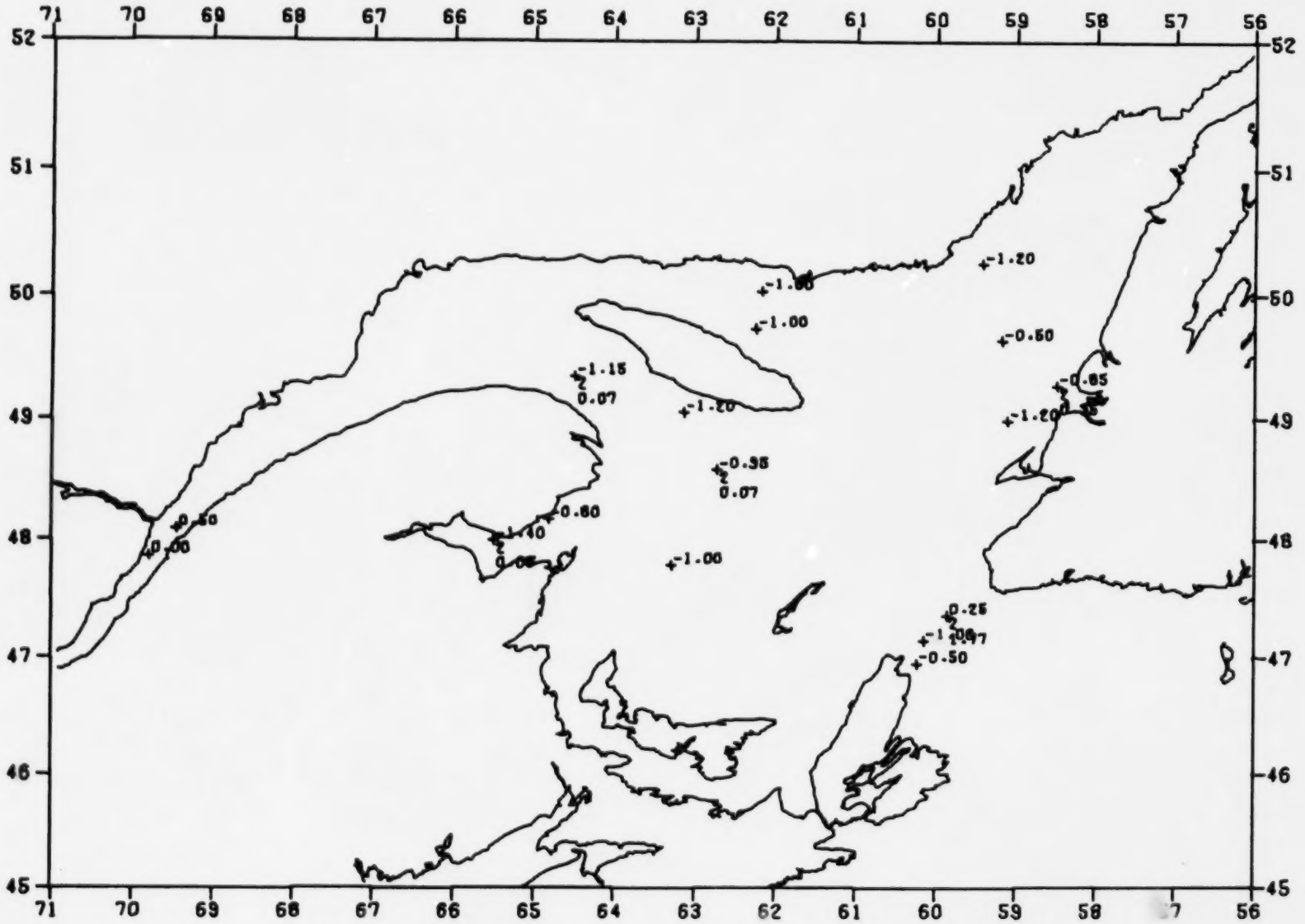

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.10
-0.30
-0.10
0.00
-0.20
2.00
-0.40
0.70
0.10
-1.20
0.10
0.48
0.42
0.73
0.75
0.21
0.40
0.37
0.55
0.36
1.03
0.88
0.43
0.71
1.20
0.53

JANUARY

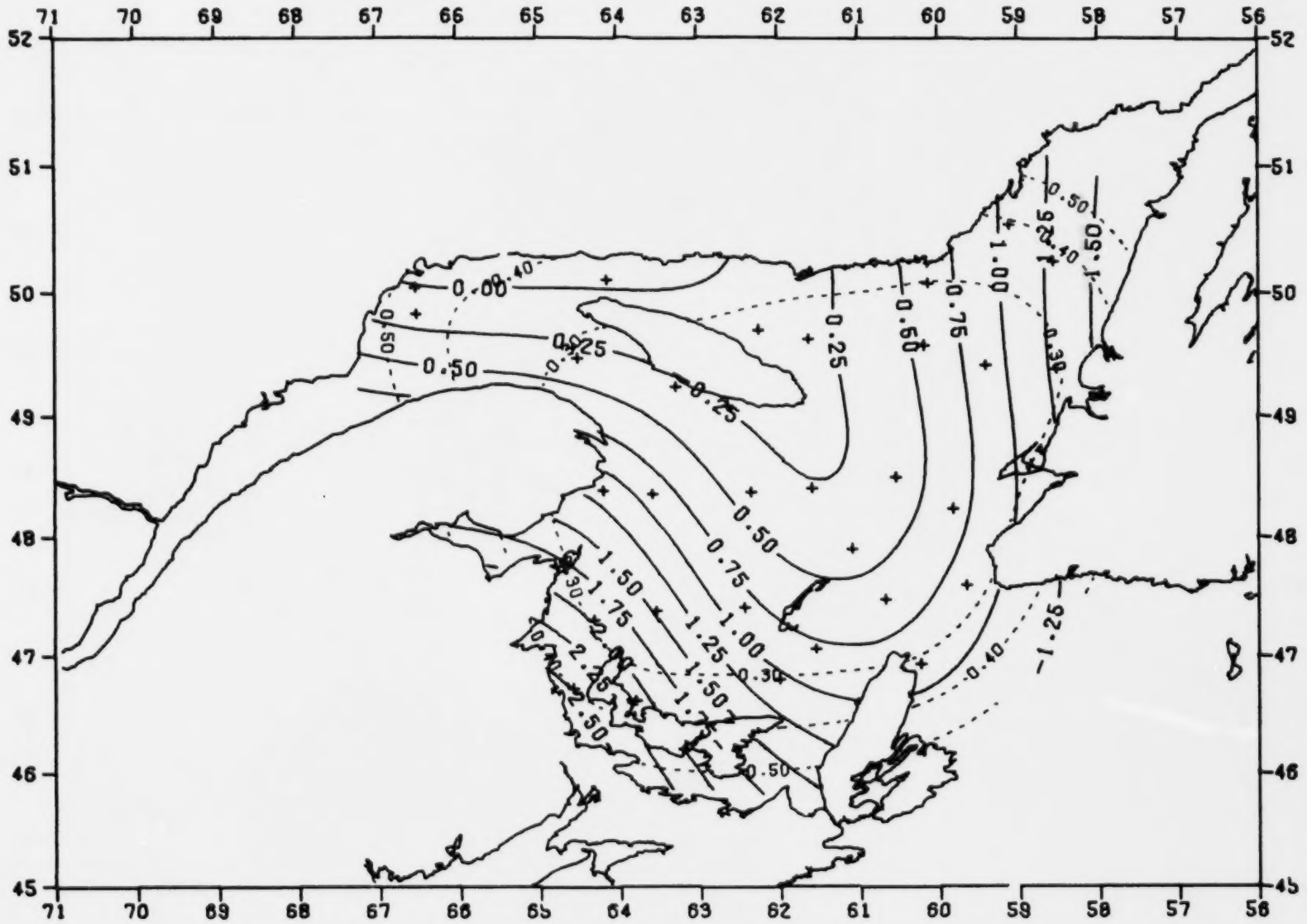

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.20
0.15
0.10
FEBRUARY


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
-1.00
-1.05
-1.00
0.00
0.00
-1.50
-1.40
0.25
0.10
0.21
-0.30
0.81
-0.75
0.92
-0.80
0.42
-1.15
0.07
-1.05
0.07
-0.40
0.80
-0.55
0.60
-0.60
-1.70
-0.85
0.21
-0.80
-0.95
0.78
-0.85
0.07
-0.82
0.30
-0.28
0.63
-0.10
-1.20
0.14
-1.30
1.80
0.00
-0.20
-0.70
-0.17
0.50
0.58
-0.17
1.18
-1.80
-1.30
FEBRUARY

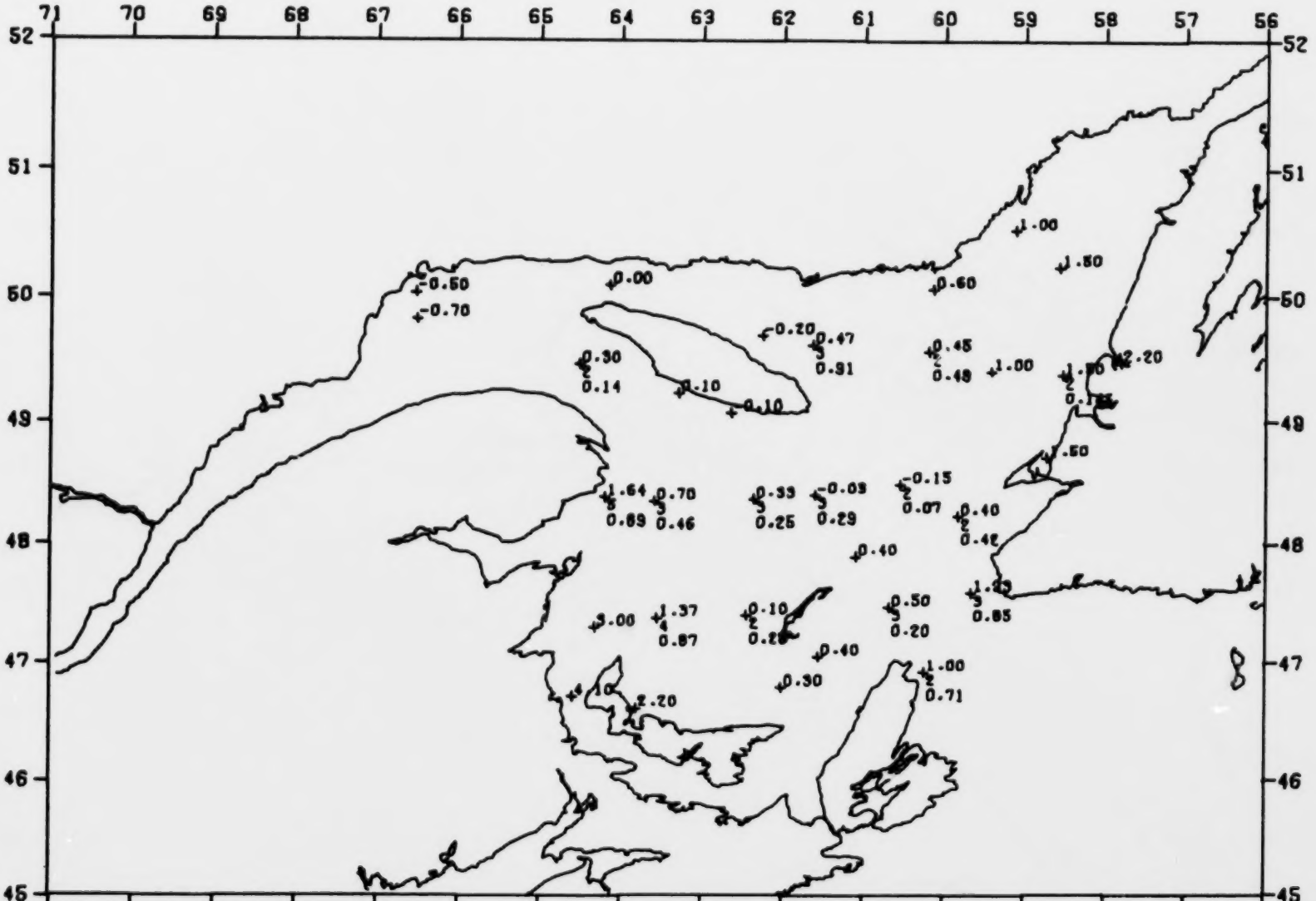

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
-0.40
-0.9
-1.0
-1.1
-0.30
-0.7
-0.8
-0.6
-0.5
-0.4
-0.3
-0.30
0.30
0
MARCH


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
-1.00
-1.00
-1.20
-0.50
-0.85
-1.20
-1.15
0.07
-1.20
-0.95
0.07
-0.80
-1.00
-0.25
-0.50
-0.50
-1.00

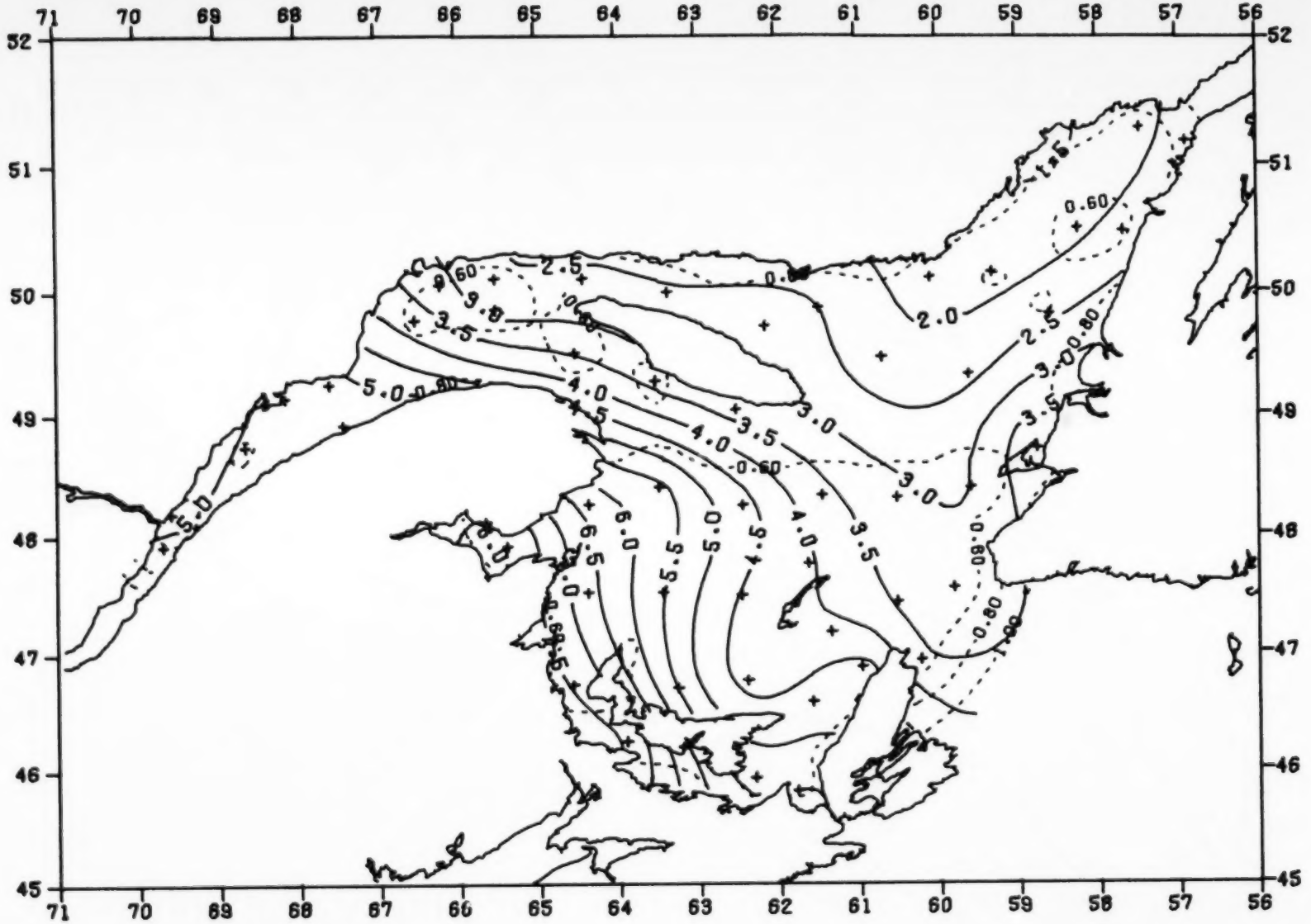
MARCH

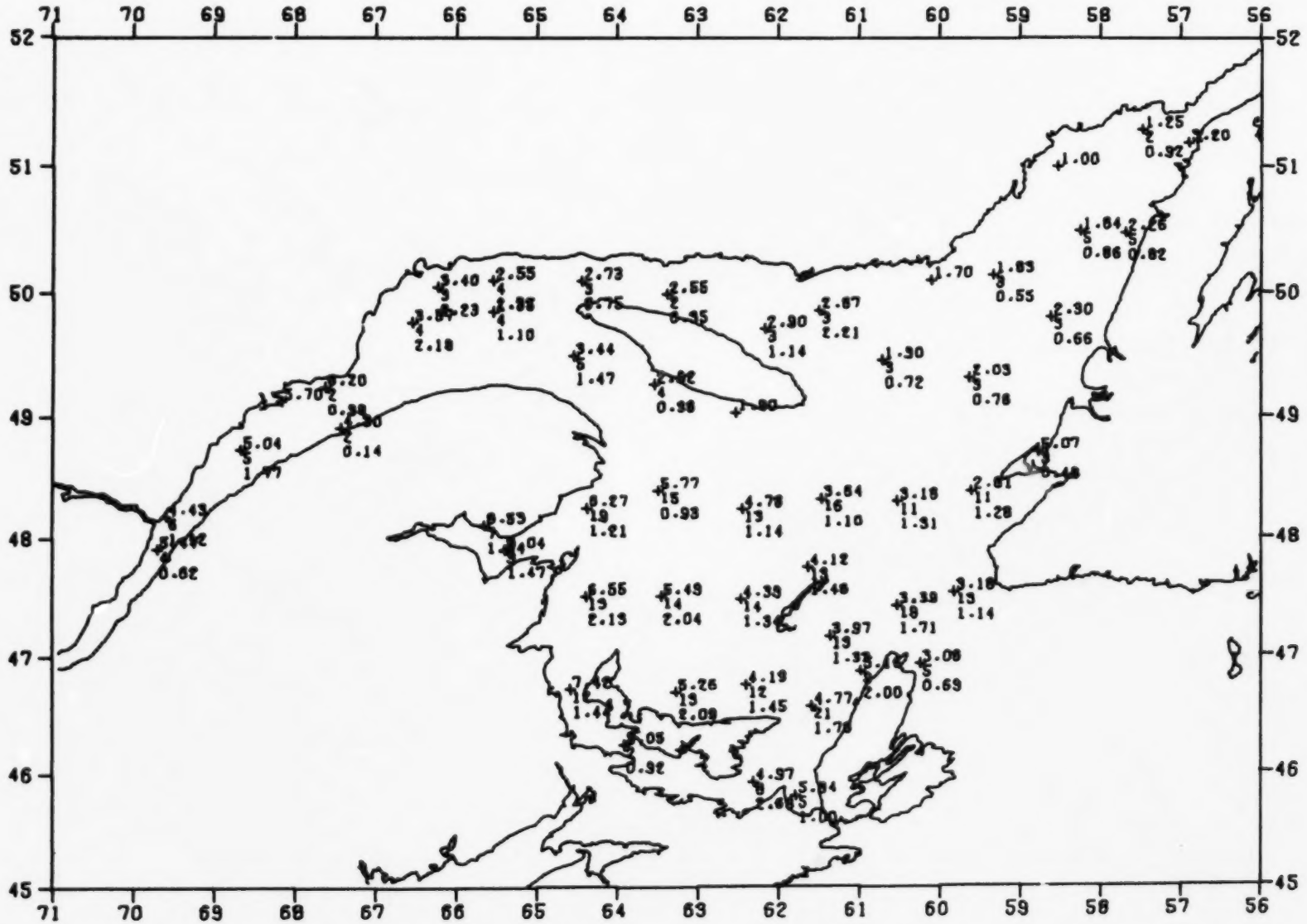

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
0.40
0.30
0.50

APRIL

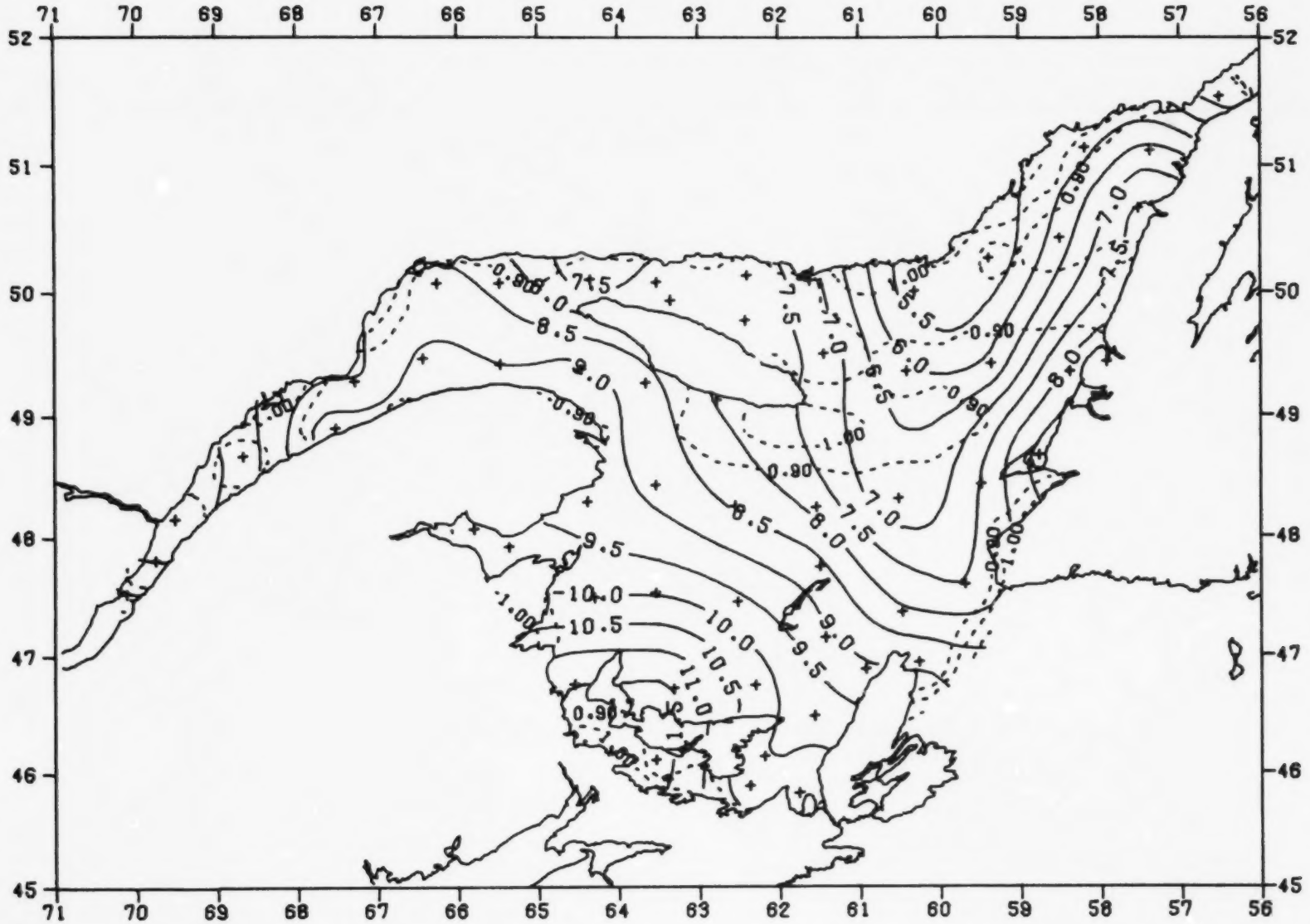

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
-0.50
-0.70
0.00
0.60
1.00
1.50
0.20
0.47
0.91
0.30
0.14
0.10
0.10
0.45
0.48
1.00
1.50
2.20
0.50
1.64
0.89
0.70
0.46
0.33
0.25
-0.09
0.29
-0.15
0.07
0.40
0.40
0.40
3.00
1.37
0.87
0.10
0.50
0.20
0.85
0.40
0.30
1.00
0.71
2.20

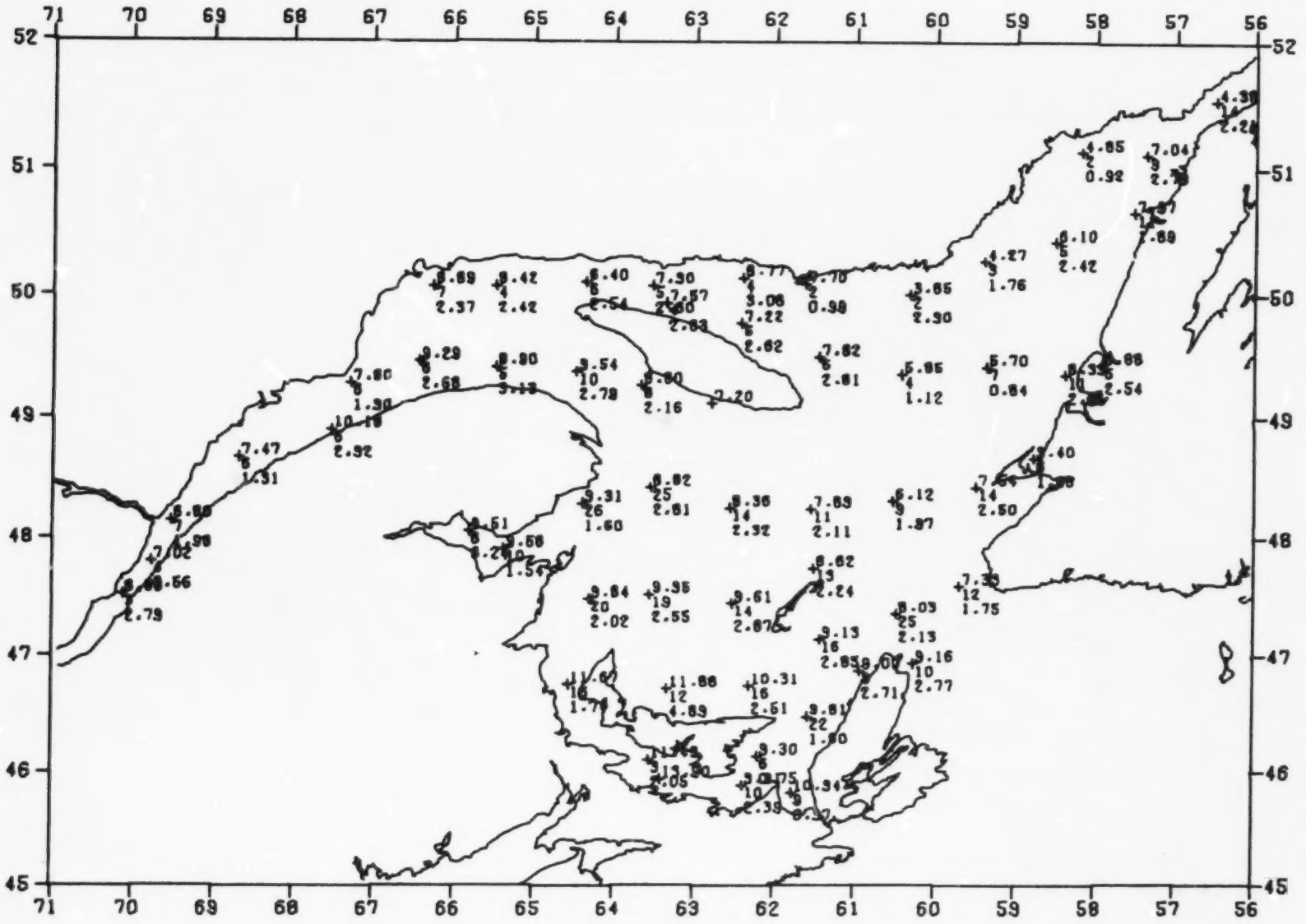
APRIL


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.60
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0.80
MAY

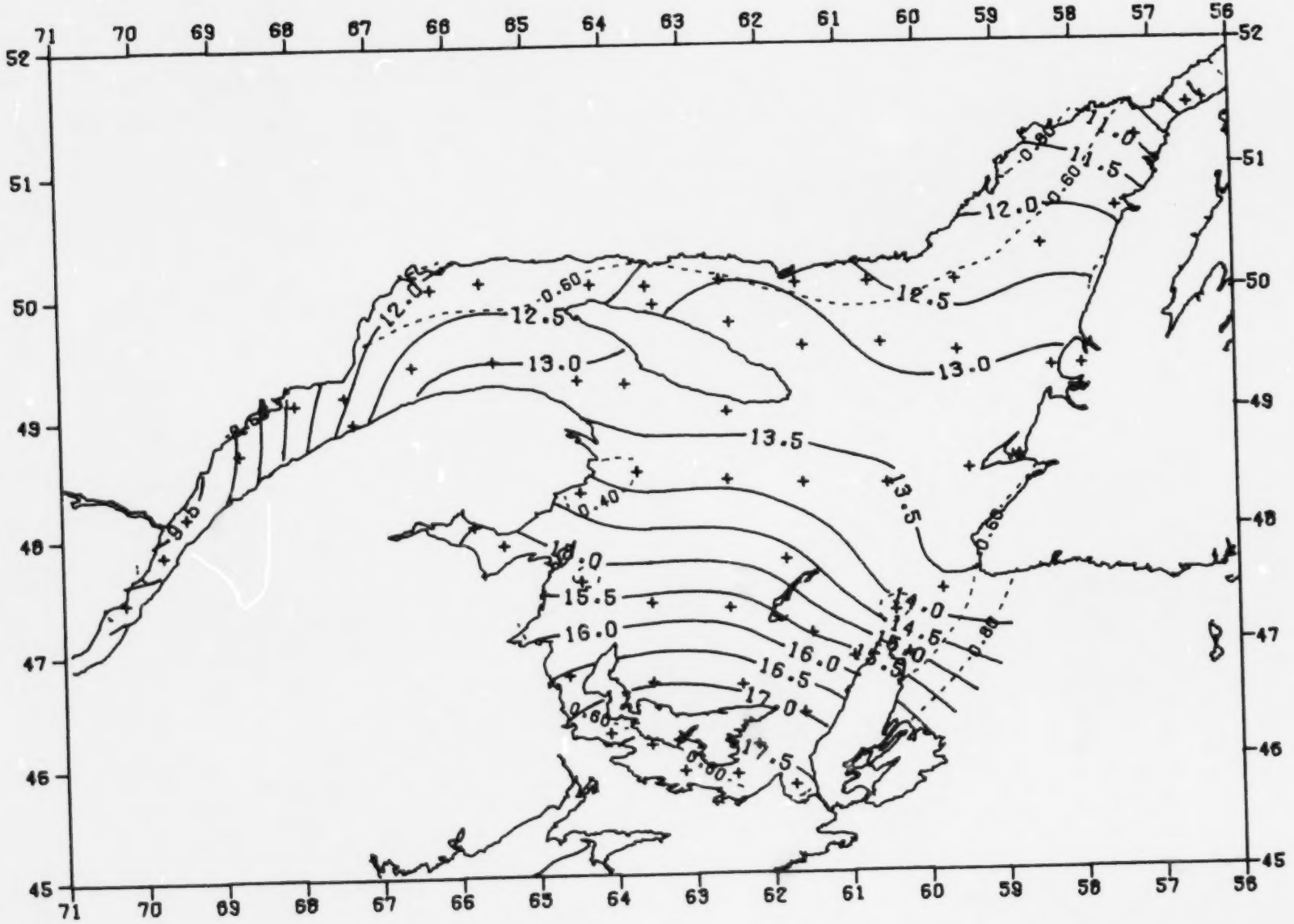


MAY

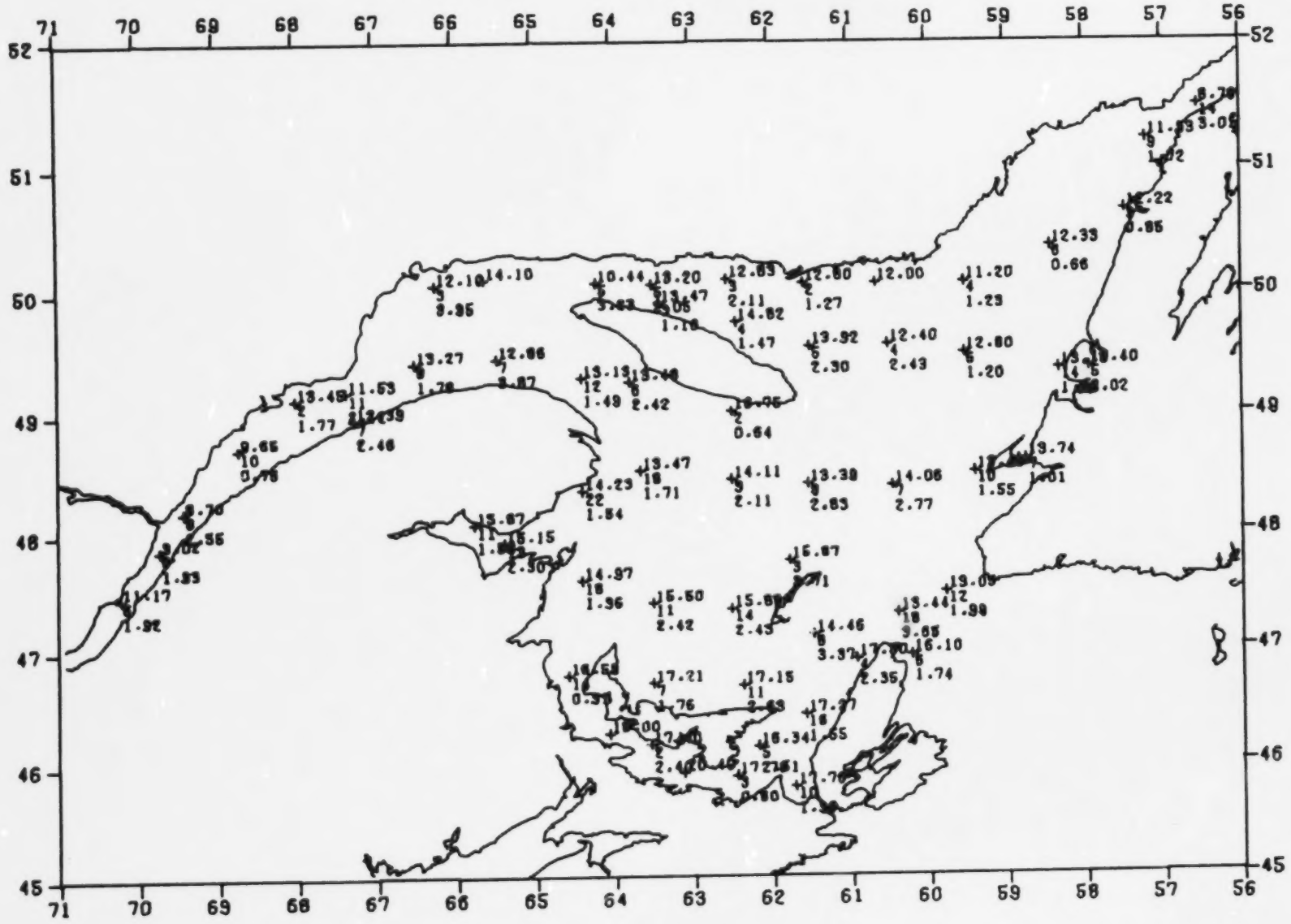

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
0.90
1.00
JUNE



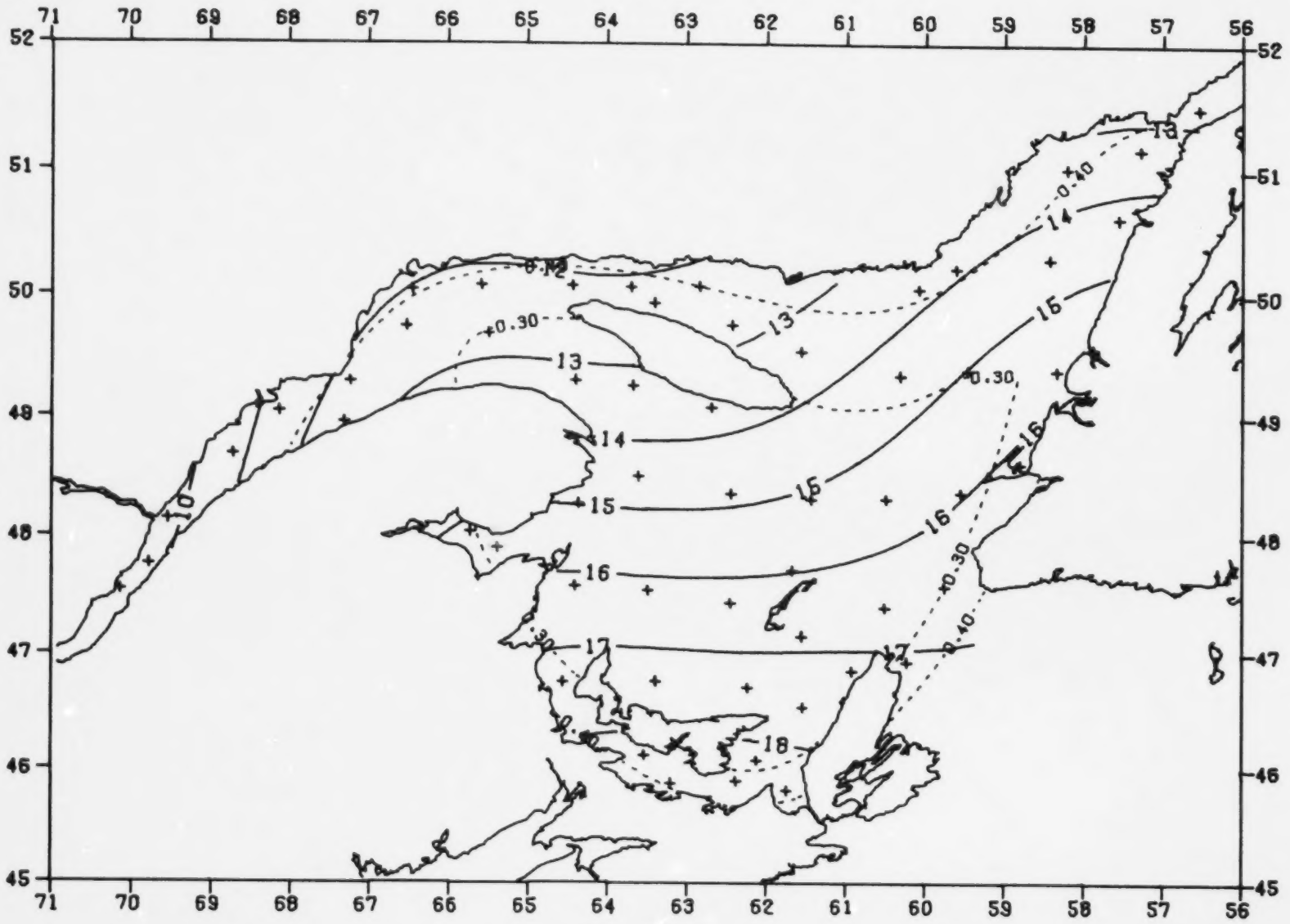
JUNE

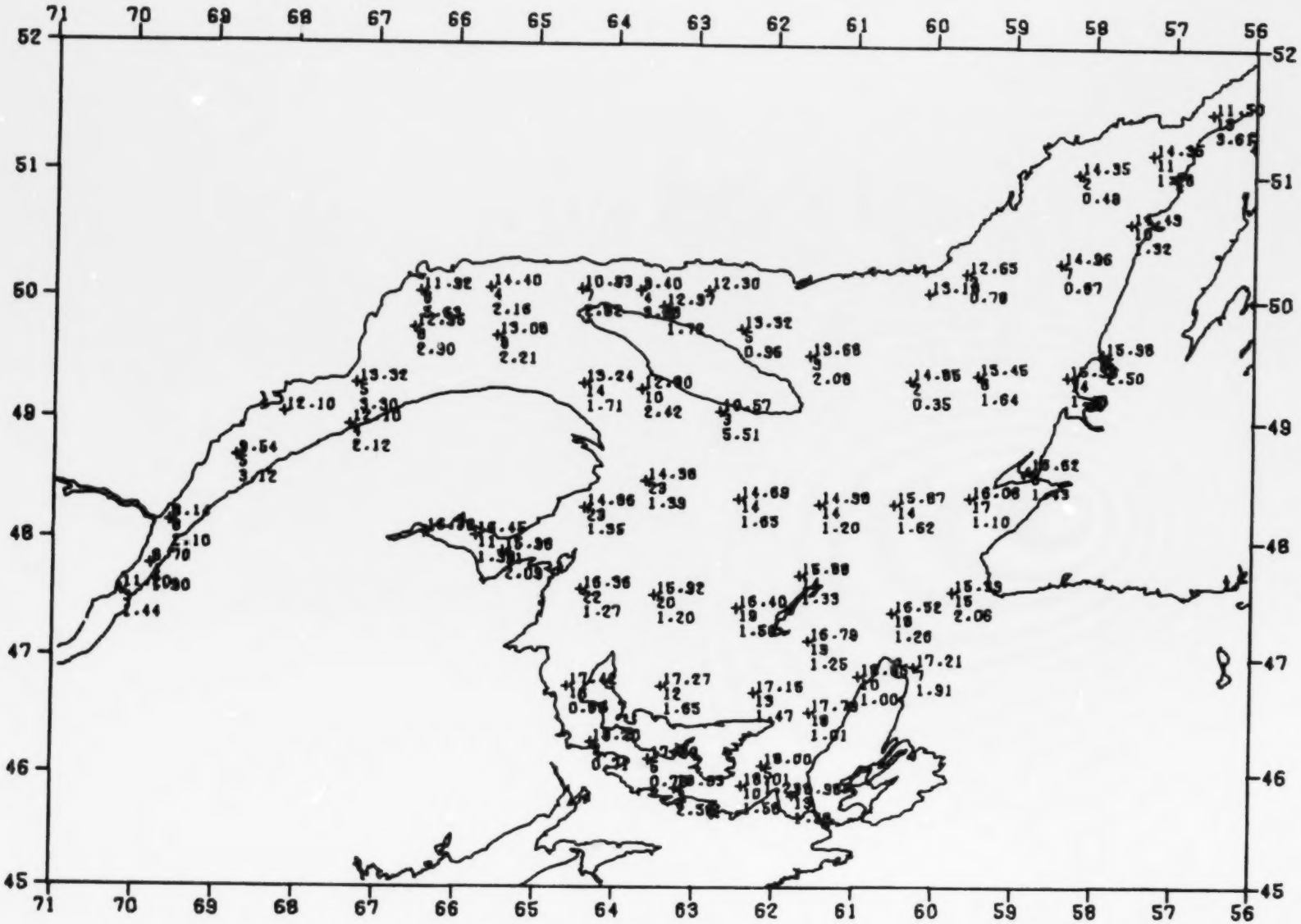

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
15.0
15.5
16.0
16.5
17.0
17.5
0.40
0.60
0.80

JULY

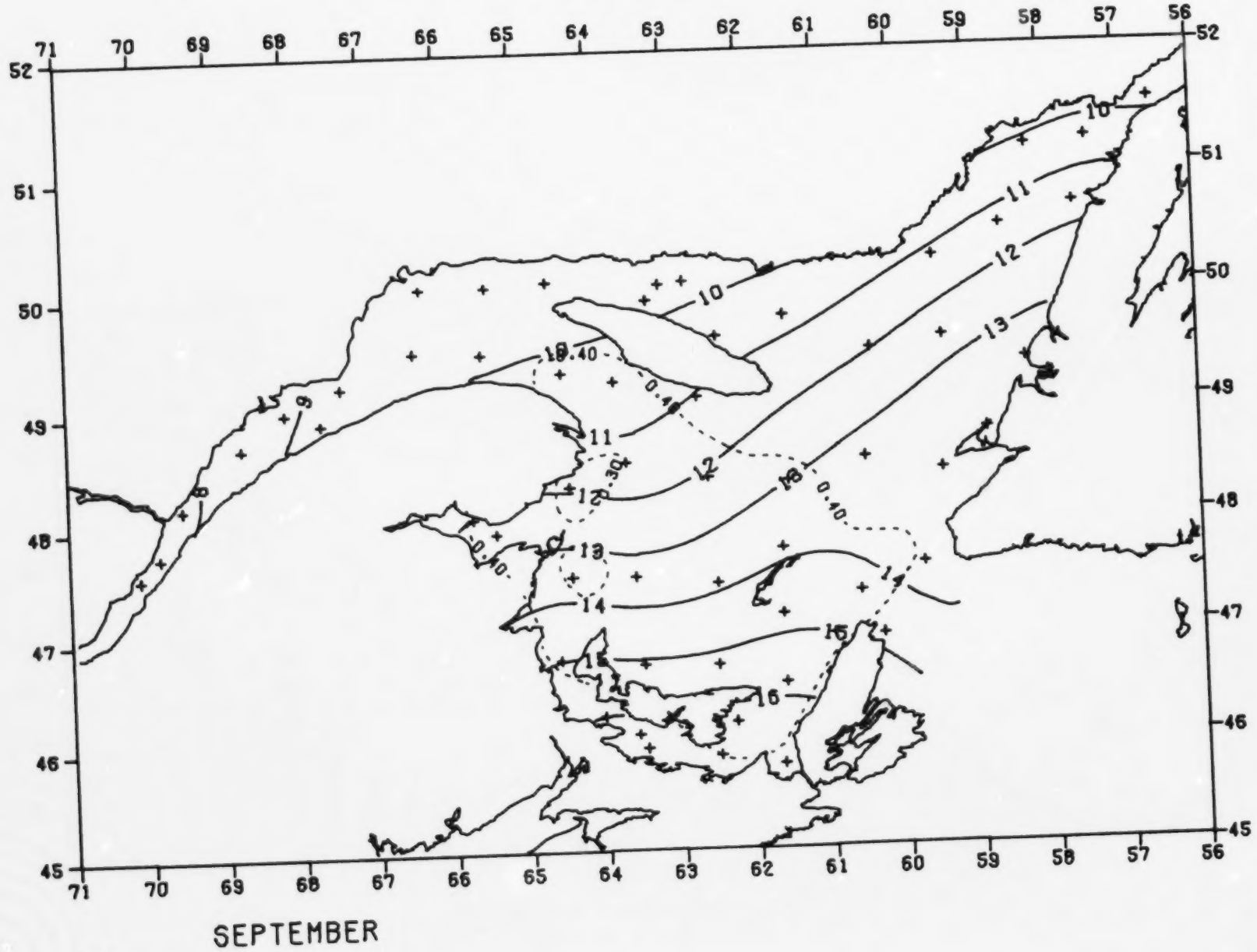


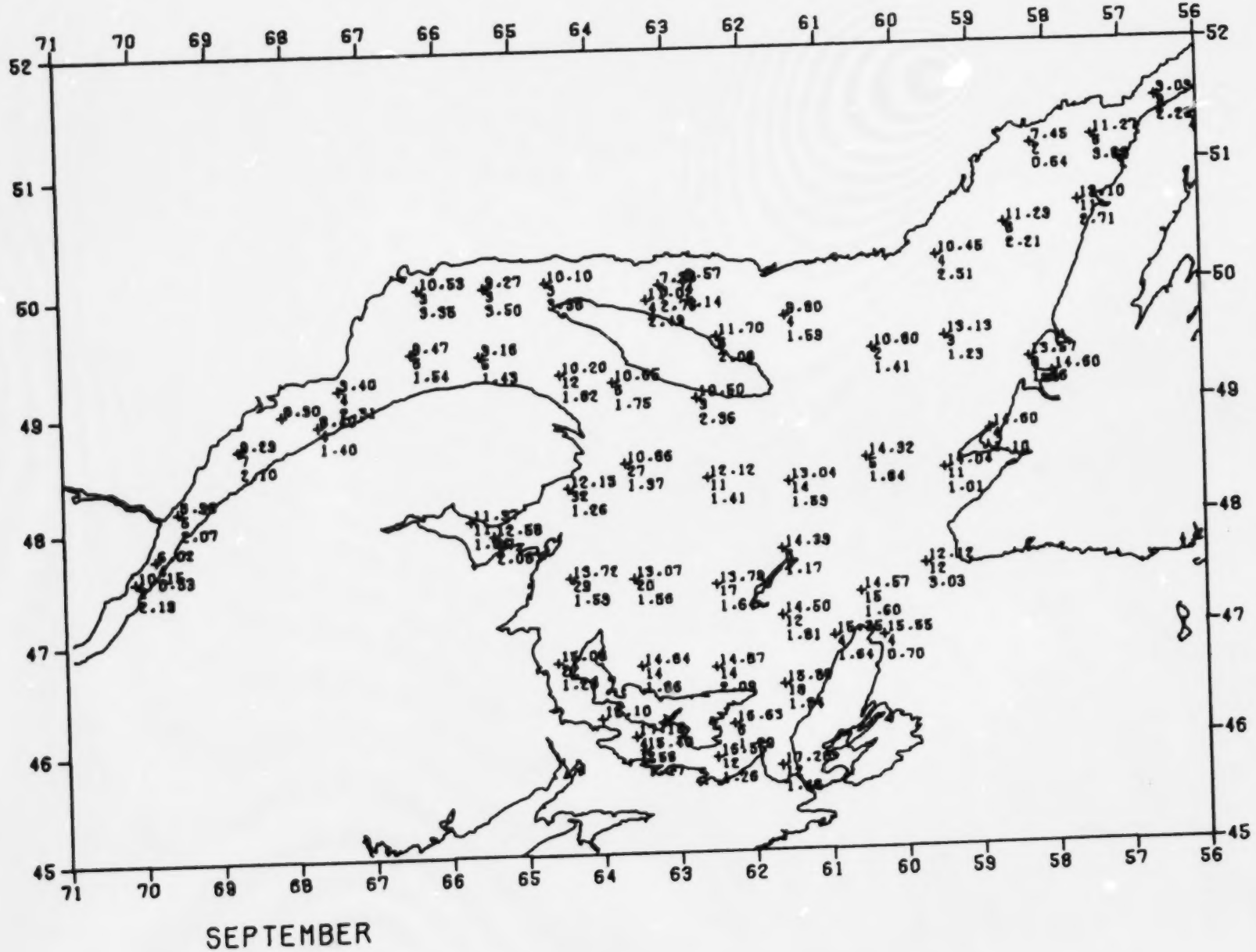
JULY


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.40
14
0.30
13
12
15
16
17
18
AUGUST

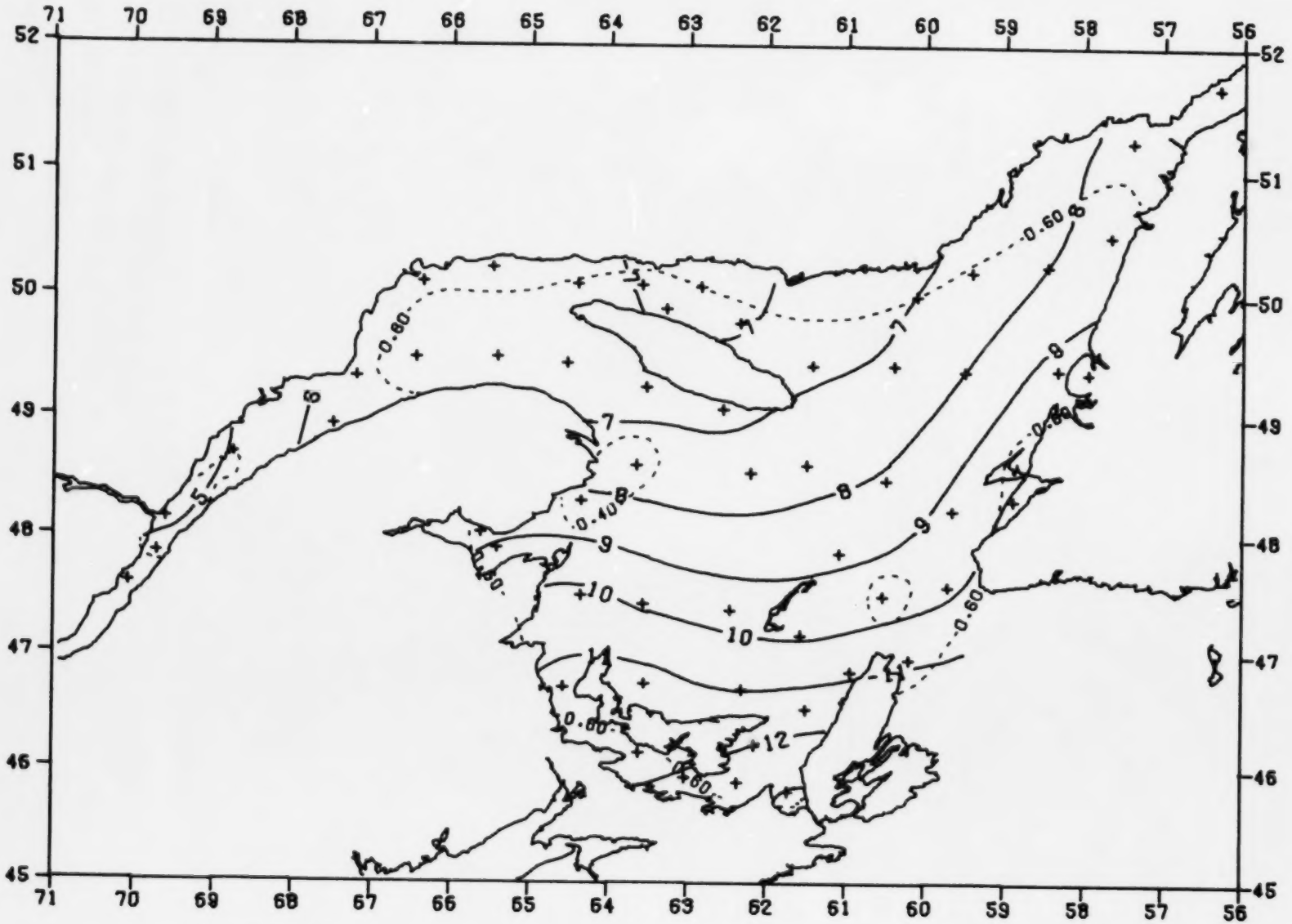


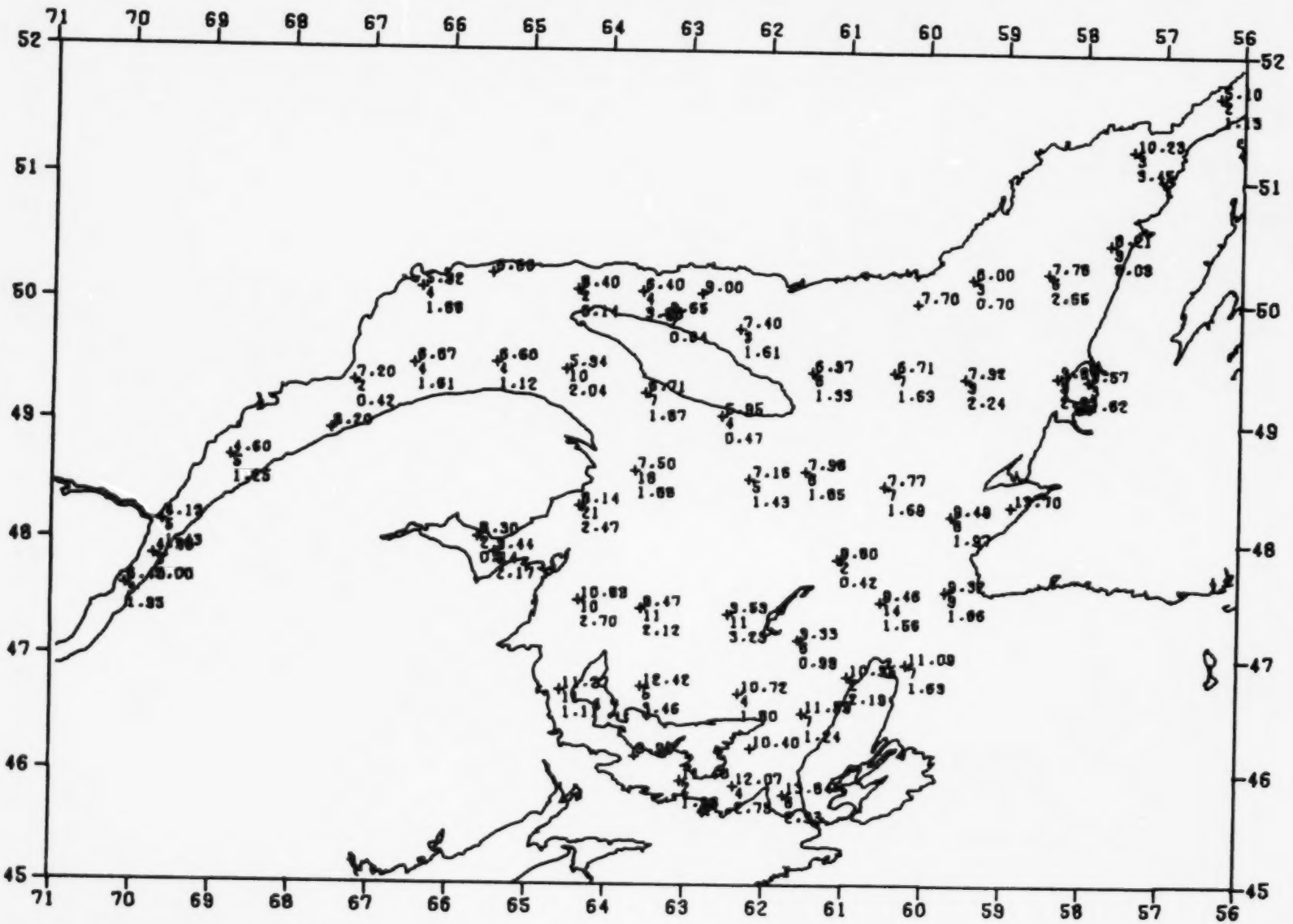
AUGUST


SEPTEMBER

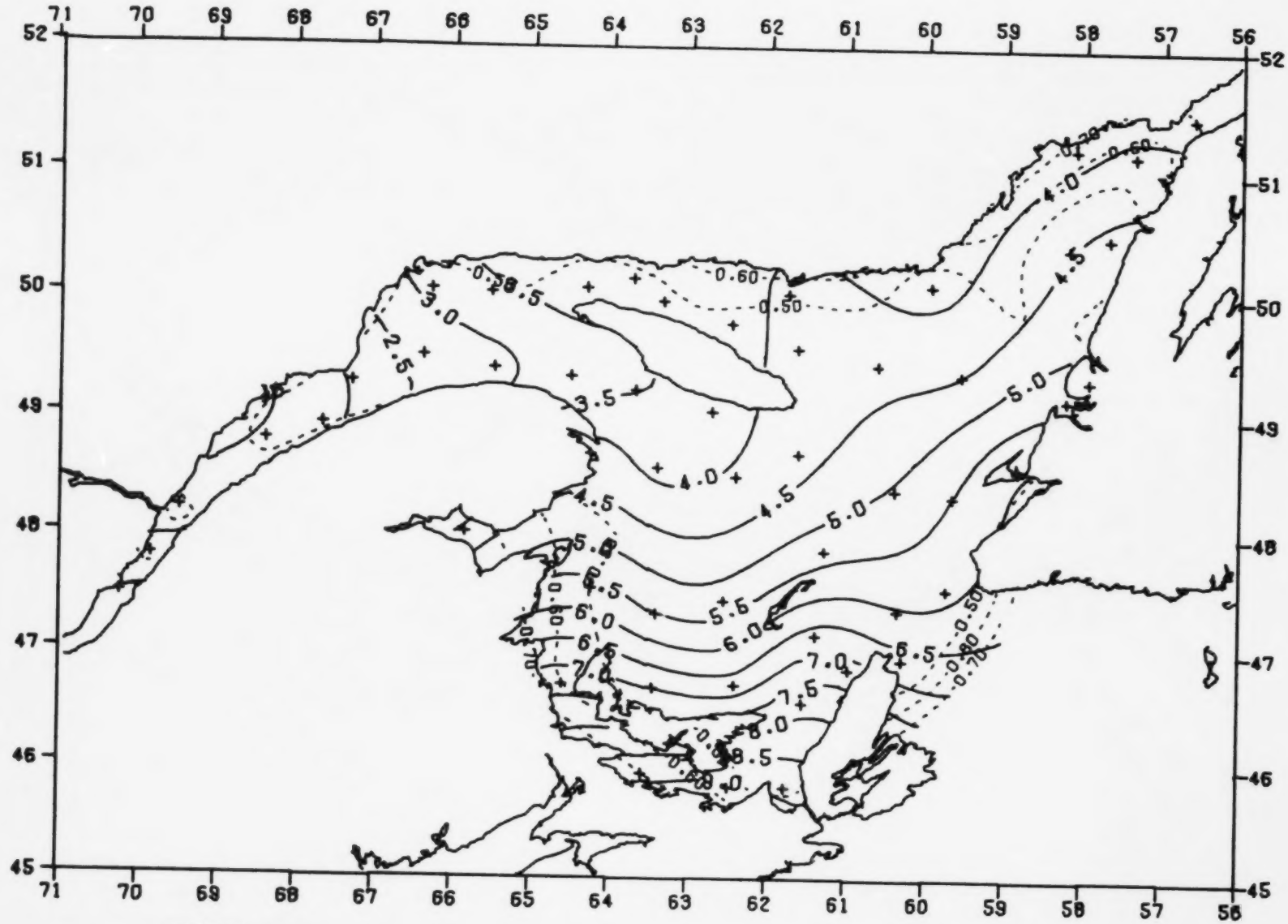


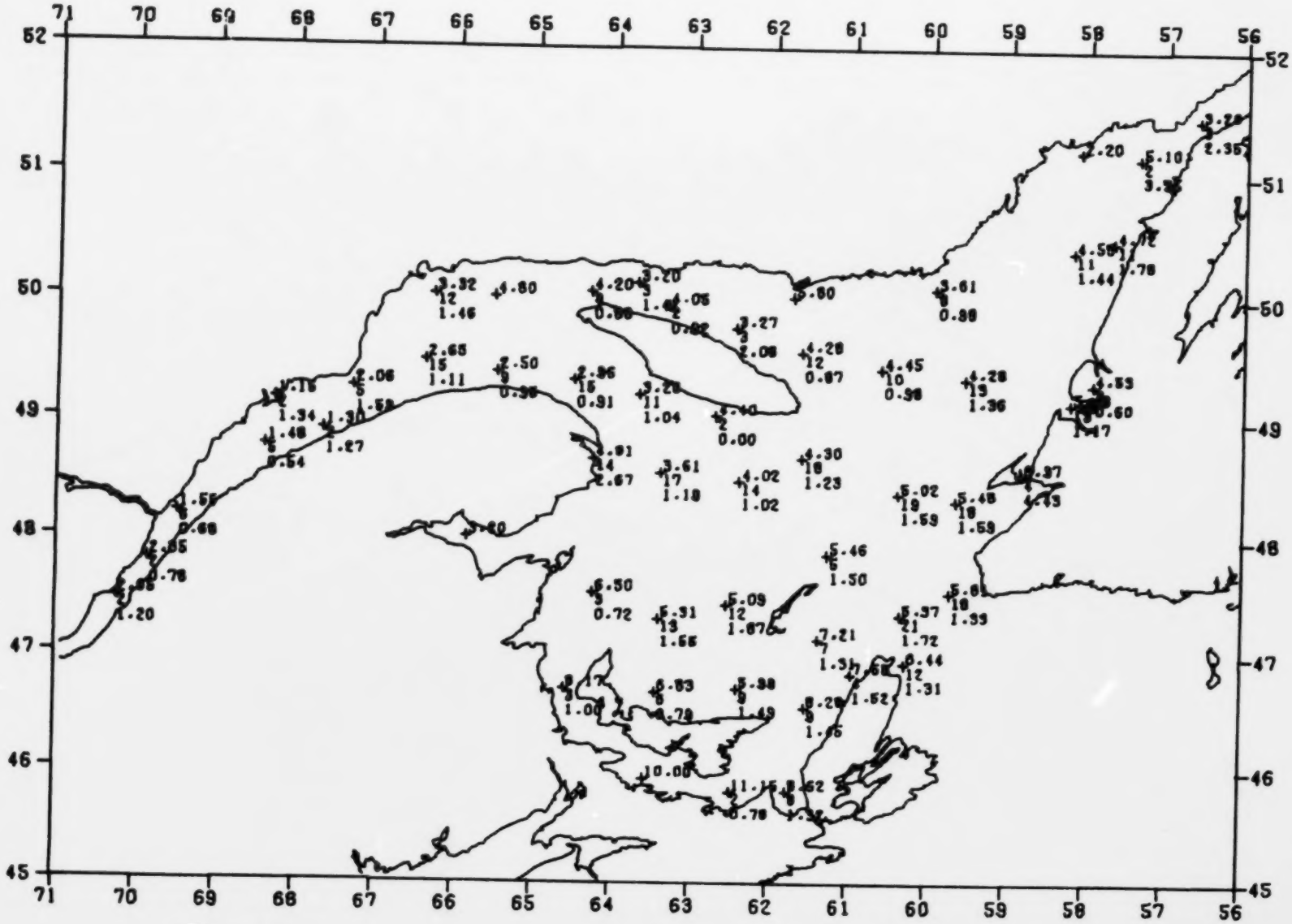
SEPTEMBER

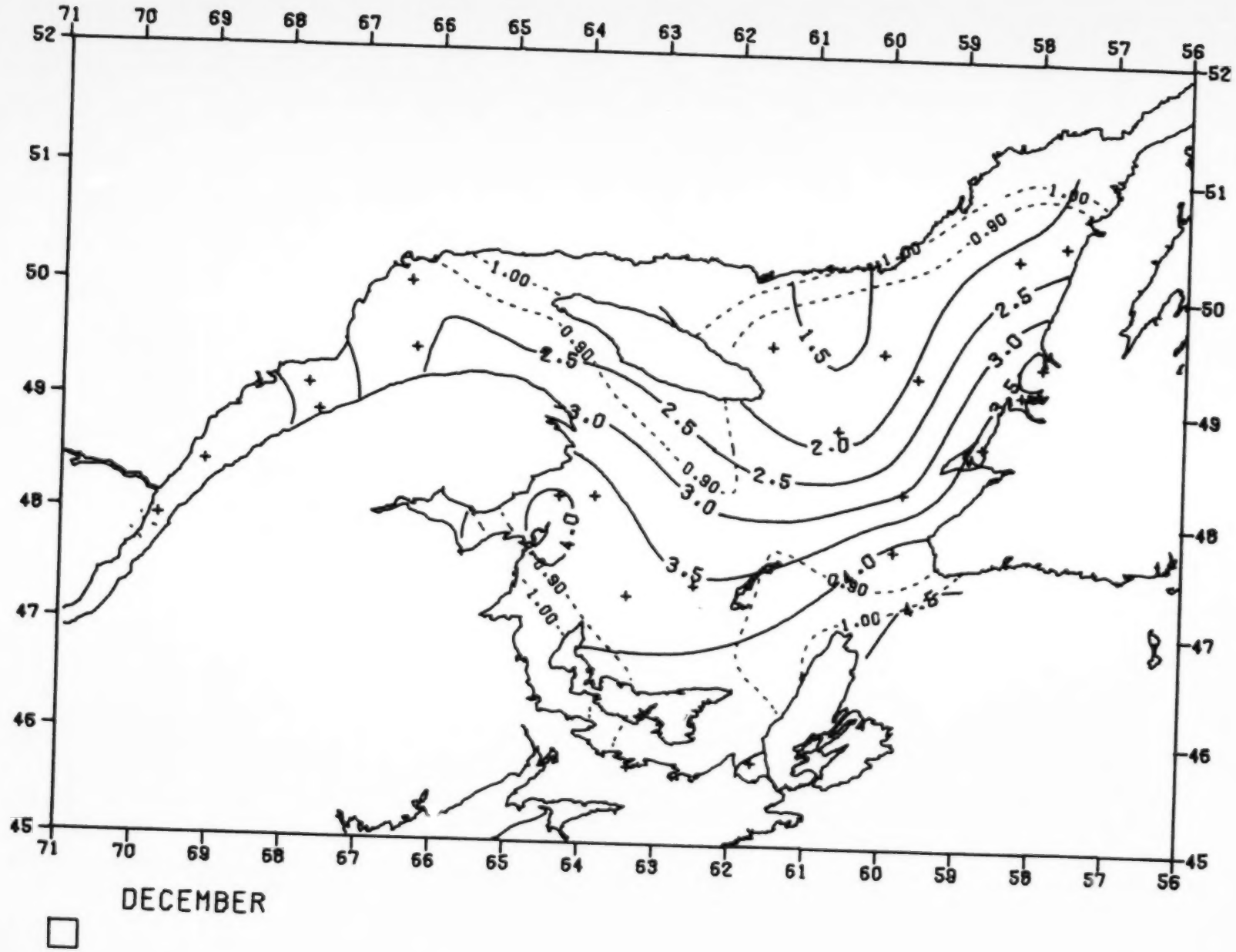

71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
0.60
0.40
5
6
7
8
9
10
11
12
OCTOBER

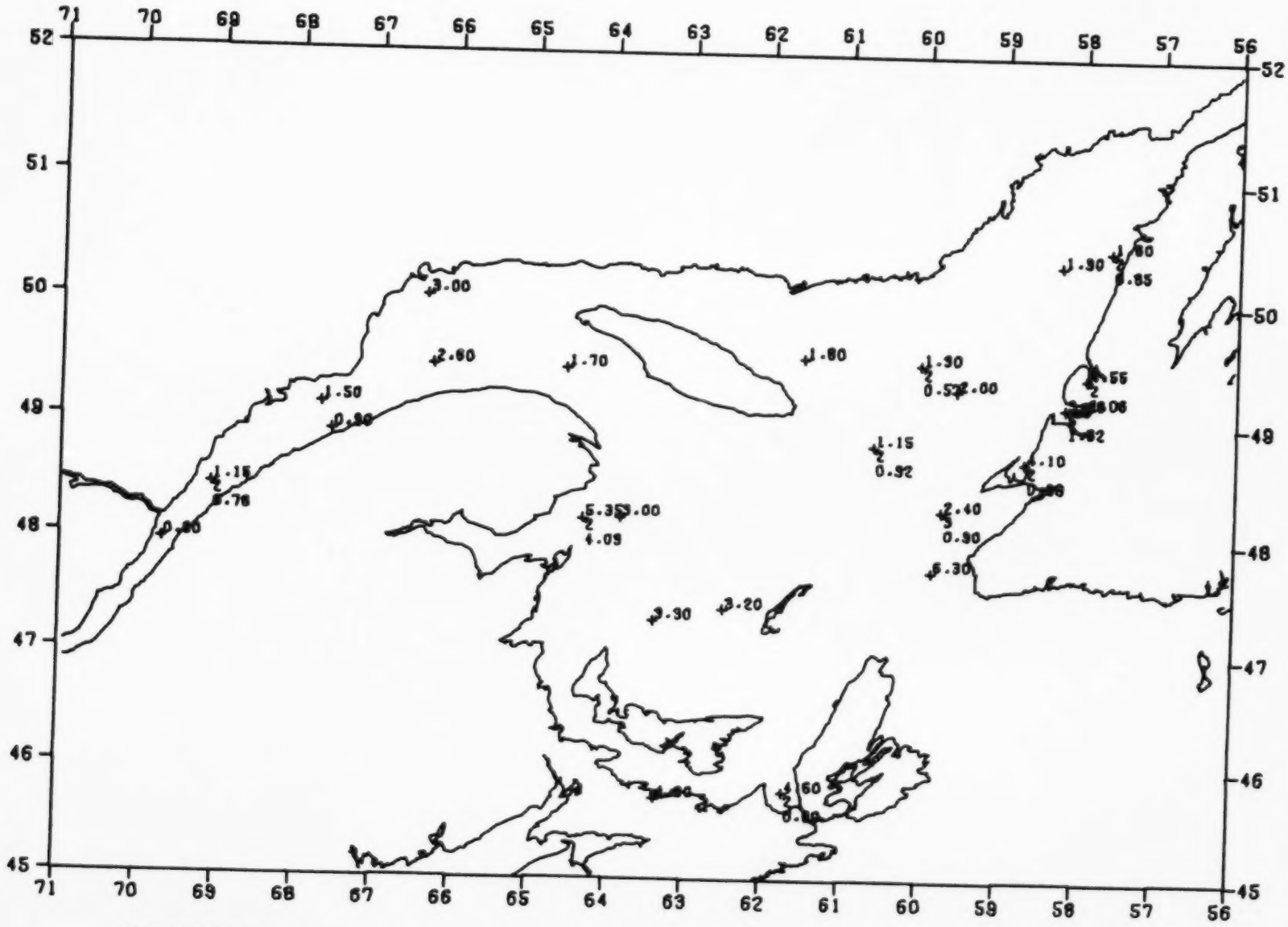


OCTOBER


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
0.50
0.60
0.70
NOVEMBER


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
NOVEMBER


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
1.00
0.90
1.5
2.0
2.5
3.0
3.5
4.0
DECEMBER


71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56
52 51 50 49 48 47 46 45
DECEMBER